University of Alberta

Correlation of Indoor Air Quality Parameters in Edmonton Public, Elk Island Public and Elk Island Catholic Schools

by

Lorelei Anne-Marie Betke

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

Environmental Science
Department of Civil and Environmental Engineering

Edmonton, Alberta
Spring, 2003

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Degree: Master of Science

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ABSTRACT

Indoor air quality was evaluated using several air-sampling tools in a sample group of schools from Edmonton and Elk Island School districts. Data collection involved completion of several questionnaires coupled with physical sampling of temperature, relative humidity, ventilation and airborne mould levels.

Two of the objectives of this study were to compile baseline indoor air quality data from Edmonton-area schools, and to look for correlations between indoor comfort parameters and airborne mould levels. The third objective was to evaluate the reliability of occupant perception of indoor environmental parameters by comparing it with measured data.

Study results indicated non-normally distributed data with a large amount of non-detectable (censored) data collected during the winter season. Subsequent non-parametric analysis of these data indicated no significant correlation between any of the comfort parameters and airborne mould levels. Additionally, no significant relationships were observed between perceived and measured environmental data.

ACKNOWLEDGEMENTS

This study was made possible by the collaboration of the Capital Health Authority, the University of Alberta and the Edmonton Public and Elk Island Public and Catholic School Boards. Thank you to these people who provided us with technical, academic and financial support.

Thank you to Dr. Warren Kindzierski and faculty members associated with the Department of Public Health and the Department of Math and Statistical Sciences for sharing advice and insight, and to Steve Probert with the Capital Health Authority for acting as a resource person throughout the project.

I am grateful to my two teammates, Corinne Stocco and Mary Unobe for their expertise in many areas, and particularly for their patience, which may have been tested once or twice.

Last but not least, I would like to extend a hearty thank you to my family and friends, who provided me with an endless stream of advice, wisdom, free lunches, and love. Thank you.

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LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
A_w	water activity
BDL	below detection limit
CHA	Capital Health Authority
CFM	cubit feet per minute
CFU	colony-forming units
CICH	Canadian Institute of Child Health
CLA	Canadian Lung Association
CLO	units of clothing
CMHC	Canadian Mortgage and Housing Corporation
EICS	Elk Island Catholic Schools
EIPS	Elk Island Public Schools
EPA	Environmental Protection Agency
EPS	Edmonton Public Schools
HVAC	heating, ventilation and air-conditioning
IAQ	indoor air quality
HREB	Health Research Ethics Board
LDL	lower detection limit
MEA	malt extract agar
NIOSH	National Institute of Occupational Safety and Health
OAI	outdoor air intake
RB	Rose Bengal
RBS	Rose Bengal-streptomycin
RCS	Reuter centrifugal sampler
RH	relative humidity
VOC	volatile organic compound
WHO	World Health Organization

1.0 INTRODUCTION

1.1 Problem Statement

Indoor air quality (IAQ) is a topic of recent interest, largely due to the "tightening" of buildings during the 1973-1974 energy crisis. With decreased ventilation rates came heightened concerns over indoor environmental quality. Diagnosis of "Sick Building Syndrome" (SBS) and its causes became the primary motivation for IAQ studies.

Recent studies have demonstrated a significant trend between IAQ problems in schools and diminished student health and performance. Researchers suggest that children's vulnerability to IAQ problems may reflect both the amount of time they spend at school and their developing immune systems (Koskinen *et al.*, 1993). Over the last ten years, the incidence of environmental-related allergies and asthma in school-age children has risen significantly. Currently, The Canadian Lung Association (CLA) (2002) estimates that up to 10% of children experience symptoms of asthma, a condition accounting for 1/4 of school absenteeism.

While environmental contaminants and associated health concerns have been the basis for many IAQ studies, the collection of baseline IAQ data has been largely ignored (Womble *et al.*, 1993). Furthermore, very few studies have examined IAQ parameters in a school environment. In 1995, The Environmental Health Directorate for Health Canada recommended research to establish baseline levels of mould contamination in public buildings (Health Canada, 1995). In addition, the Canadian Institute of Child Health (CICH) advised the creation of school action plans to address IAQ concerns (CICH, 1998). In 2000, prompted by growing concerns from parents and teachers in Edmonton and surrounding communities, the Capital Health Authority (CHA) launched a study into the IAQ of Edmonton-area schools.

1.2 Study Objectives

In 2000, the CHA proposed an air quality study. The primary objective of the study was to establish baseline IAQ parameter levels in school environments. Environmental factors thought to be most directly associated with IAQ and associated health and comfort concerns include airborne mould levels, temperature, and relative humidity (RH). Ventilation is further thought to have a direct effect on indoor contaminant levels. Two of the graduate students involved in the study, Corinne Stocco and Mary Unobe, investigated the collection of IAQ parameters.

A secondary objective of the study and the basis of this thesis was to investigate possible relationships between selected IAQ parameters and aerosol mould levels. The association between indoor RH, temperature, ventilation and airborne mould levels was evaluated to determine if a dose-response relationship existed between variables. Hypothetically, correlations observed between environmental parameters might then be applied to the development of an IAQ management strategy.

A final objective of this thesis was to identify possible relationships between human perception of IAQ and environmental parameters. While past studies have examined relationships between physical symptoms and parameter measurements, few have analyzed dose-response relationships between perception and IAQ parameters. Determination of a positive association between human perception of IAQ and parameter measurements might be formative in enabling investigators to pinpoint problem environments before hazardous conditions arise.

1.3 Hypothesis

A 1988 study of IAQ in Edmonton schools uncovered very few environmental concerns (Keen Engineering, 1988). Furthermore, low RH, typical in Alberta, is not conducive to mould propagation. Consequently, investigators did not expect to encounter many IAQ problems in school environments. From the literature, IAQ parameters such as humidity, ventilation rate and occupancy level were anticipated to have an effect on mould levels. However, the range of temperatures expected in classrooms was not projected to significantly affect airborne mould levels. Finally, investigators hypothesized that relationships such as those previously observed between subject symptomatology and IAQ might also exist between perception of indoor air parameters and actual measurements.

2.0 BACKGROUND INFORMATION

2.1 Timeline of Indoor Air Quality Issues

Since early in this century, episodes of extreme air pollution in highly industrialized and urbanized locations have focused attention on the quality of the air we breathe and the associated health concerns. Incidents such as "The Great London Smog" of 1952, precipitated by heightened levels of sulfur dioxide (SO_2) and smoke, led to 4000 deaths and prompted public demands for improved air quality (Mage, 1996; Pearce, 1992).

The first studies on IAQ measured indoor concentrations of pollutants that had previously been measured outdoors, particularly SO_2, carbon monoxide (CO) and total suspended particles (Nagda, 1987). In 1958, researchers initiated formal indoor air studies by completing a study of the effects of indoor air pollution on pulmonary function of respiratory cripples in Cincinnati (Mage, 1996). Indoor air studies in 1964 and 1967 again suggested a hazardous relationship between indoor smoke levels and health effects and warned that indoor air pollution had been "a neglected variable in epidemiology" for too long (from Mage, 1996).

A worldwide energy crisis in 1973-1974 caused oil prices to rise from $3 to $30/barrel. To reduce energy expenditures, building owners "tightened" structures to limit the infiltration of outside air. Tightening was largely accomplished through increased insulation, installation of vapour barriers and sealing of leaking windows (Hansen, 1999). Fewer air exchanges per hour led to a buildup of indoor contaminants and collection of moisture within the structures, enabling growth of microorganisms and precipitating a series of complaints from building occupants (Hansen, 1999).

In addition to the "tightening" of buildings within the past half-century, construction materials have changed. Post-World War Two, heightened demand for improved housing outstripped the ability to meet the needs with traditional building materials such as wood. Fifty years ago, both interior and exterior walls were constructed out of steel or masonry materials such as concrete block, clay tile and plaster (Ellringer *et al.*, 2000). In addition, it was common to cover wooden studs with metal mesh and plaster, a type of wall construction very resistant to mould colonization, due to low levels of cellulose-containing materials. Today it is common to construct walls with gypsum wallboard and fibrous glass insulation, materials that permit mould colonization if adequate moisture is present. (Ellringer *et al.*, 2000). Furthermore, contaminated materials such as carpet, ceiling tile, wallpaper, flooring, insulation, and HVAC components may act as indoor biopollutant reservoirs. Colonization and amplification on these materials is thought to be based on available nutrients and moisture levels (Foarde *et al.*, 1996).

Over the last 10 to 15 years, there has been a steady increase of IAQ complaints from a variety of residential, occupational and institutional settings. Currently, The World Health Organization (WHO) estimates that as many as 30% of all buildings may be "sick" (Burton, 2000).

Recent studies suggest that IAQ may be a significant problem in schools. An investigation by the U.S. Government's General Accounting Office (GAO) in 1996 estimated that IAQ problems are experienced by as many as 20% of all public schools in North America (GAO, 1996). Quality of indoor air in schools is receiving increasing attention as new studies indicate that IAQ may impact both student health and performance (Bayer *et al.*, 1999). In a 1993 study, Qin *et al.* (1993) calculated that children in industrial countries spend approximately 81% of time indoors in the winter, and 75% of time indoors in the summer. Consequently, 70-80% of air inhaled by children is indoor air with contamination levels estimated to be 10 to 100 times the level of outdoor contaminants. Furthermore, young children are thought to be at a higher risk of developing health problems such as asthma from indoor pollutants than adults are, possibly due to their underdeveloped immune systems (Koskinen *et al.*, 1993). According to the Canadian Lung Association (CLA), asthma currently affects between 7-10% of the pediatric population and may account for up to 25% of all school absenteeism (CLA, 2002). The last five decades have witnessed an increase in studies on IAQ, now considered one of the major areas of intervention in health-related research (Maroni, 1995).

2.2 IAQ-Related Health Issues

Recent studies have linked symptoms and health complaints of building occupants with increased levels of indoor contaminants (Burton, 2000). To better understand these environmental health issues, researchers have attempted to classify symptom sets as definable ailments. Building-Related Illness (BRI) encompasses all diagnosable illnesses that can be attributed to specific environmental agents in the air (Maroni, 1995). Legionnaire's disease, humidifier fever, hypersensitivity pneumonitis and asthma fall into this category (Glenn, 1994). By contrast, SBS describes a set of symptoms that are thought to be related to an indoor air contaminant or agent (Etkin, 1994). WHO defines SBS as an excess of work-related irritations of the skin and mucous membranes and other symptoms, including headache, fatigue, and difficulty concentrating (Menzies *et al.*, 1993). Studies suggest that IAQ in specific indoor environments may be suspect if symptoms occur at least once a week and improve when away from the institution (Burton, 2000).

SBS has only been recognized as a definable health ailment for approximately 25 years, with the first official study of the phenomenon occurring in 1984 (Finnigan *et al.*, 1984). Despite this, the U.S. Occupational Safety and Health Administration (OSHA) estimates that between 30-70 million US workers are affected by SBS (Mikatavage *et al.*, 1995; Arnold, 2001).

2.3 Factors Influencing IAQ

Since the 1970s, The National Institute for Occupational Safety and Health (NIOSH) has categorized the causes of 1,500 IAQ episodes as follows (Burton, 2000):

- 50% was attributed to deficiencies in building ventilation including poor air distribution, lack of outside air, uncomfortable temperatures and humidity.
- 30% was caused by indoor air contaminants, including microbiological agents.
- 10% was attributed to outdoor sources including motor vehicle exhaust, and mould.
- 10% had no observable cause.

From these findings, ventilation problems, humidity and temperature levels and microbial agents emerge as key components of IAQ.

2.3.1 Ventilation

ASHRAE Standard 62-1999 defines ventilation as:

> "The process of supplying and moving air by natural or mechanical means to and from any space" (ASHRAE, 1999).

The effectiveness of a ventilation system in delivering outside air to the occupied zone of a building is controlled by many variables, including the configuration of the supply and return air circuits, the rates of total air circulation and outside air flow, the air supply discharge speeds, and the presence of interior partitions (Offermann and Int-Hout, 1989). Nominal ventilation rate (air exchange rate) may be defined as the rate at which outside air is delivered to a building divided by the volume of the indoor airspace (Offermann and Int-Hout, 1989). However, mechanical ventilation only accounts for a fraction of the total ventilation. Leakage through windows, doors and vent lights may also be substantial (Van Dongen and Phaff, 1989).

The majority of building ventilation problems include: inadequate fresh air supply, poor air distribution and mixing, draftiness, pressure differences between office spaces, temperature and humidity extremes or fluctuations, and air filtration problems caused by improper or no maintenance of the building ventilation system (NIOSH, 1987).

2.3.1.1 Health Effects

Ventilation has long been recognized as a key component for satisfactory indoor air. Approximately 150 years ago, DB Reid, reflecting on the importance of a good indoor environment, wrote:

> "No other cause, at least in modern times, appears to have inflicted so great an amount of evil upon the human race as defective ventilation" (As quoted in Hansen, 1999).

More recently, a study by the National Institute for Occupational Safety and Health (NIOSH) found inadequate ventilation to be the most frequent source of IAQ problems in the work environment (52% of the time) (NIOSH, 1996).

Low ventilation rates are thought to contribute to higher indoor concentrations of air pollutants, and in turn, symptoms of SBS. Sundell and Lindvall (1993) demonstrated weak correlations between low ventilation rates and SBS symptoms, including "fatigue, headache, nausea/dizziness and difficulty concentrating". Mendell (1993) also noted an association between symptoms and ventilation rates below 20 cubic feet per minute (CFM) per person. By contrast, higher ventilation rates have been associated with the reduction of selected SBS symptoms by 70-85%. Heightened ventilation rates may also dilute concentrations of airborne microbes. For example, Burge *et al.* (1990) demonstrated a relationship between increased ventilation and diminished rate of viral respiratory infections.

However, other studies refute the idea of a dose-response relationship between ventilation and SBS by demonstrating that increased ventilation alone will not likely reduce complaints among building occupants (Menzies *et al.*, 1993; Hodgson *et al.*, 1991; Fanger, 1989). Menzies *et al.* (1991) observed no improvement in environmental satisfaction scores under higher ventilation rate conditions. Studies by Jaakola *et al.* (1991) failed to indicate a relationship between SBS symptoms and varying ventilation rates (15 cfm to 150 cfm per person). In fact, in a 1984 problem building study, investigators observed a positive trend between symptoms prevalence and ventilation rates. The floor with the highest ventilation rate (83 cfm/person) had the highest symptom prevalence while the floor with the lowest ventilation rate (18 cfm/person) had the lowest prevalence of symptoms (Godish and Spengler, 1996).

Both mechanical and natural ventilation may also be associated with the sensation of draft. Houghten *et al.* (1938) developed one of the earliest investigations on discomfort due to draft and defined it as an environmental condition that causes a local sensation of coolness.

2.3.1.2 Standards

Early studies identified the need for adequate ventilation to minimize contaminants and maximize comfort levels. During the 1800's, recommendations for ventilation rates varied widely, both in quantity and units of measurement. Early on, a ventilation rate of 4 cfm/person of airflow was recommended in order to prevent the sensation of stuffiness. In 1887, researchers recommended a ventilation rate that would limit microbiological contamination to 20 organisms/L in domestic and school environments (Janssen, 1999). Finally, an air exchange rate of 30 cfm/person was recommended in 1893 and was adopted as a ventilation standard by the American Society of Heating and Ventilation Engineers (ASHVE) (Janssen, 1999).

In 1936, researchers established a minimum ventilation standard of 10 cfm/person based on the threshold detection level of human body odors (Arnold, 2001). In spite of this, the 1973 oil embargo led to national energy conservation measures calling for a reduction in this rate to 5 cfm/occupant in non-smoking environments and 25 cfm/occupant in smoking environments (Arnold, 2001). However, researchers suggested that a higher delivery of outdoor air was necessary to dilute occupant odors (Janssen, 1999). Consequently, in 1989, ASHRAE revised its minimum ventilation standard to 15-20 cfm of outdoor air per person (ASHRAE, 1989). Recommended amounts vary according to environment; for example, 20 cfm/person is required for office spaces and conference rooms, 15 cfm/person for reception areas, and 60 cfm/person for smoking lounges (NIOSH, 1996). In addition, ASHRAE proposed a minimum outdoor air requirement for classrooms of 15 cfm per person to a maximum density of 50 people/1000 ft^2 (Bearg, 1993). Table 1 lists minimum recommended ventilation levels for various school rooms. In a study of Canadian schools, 71% of classrooms failed to meet ASHRAE ventilation standards (Bayer *et al.*, 1999).

Ventilation recommendations in cfm/occupant are historically based on body odor and smoking but do not adequately address contaminant concentrations that are non-occupant related (Fanger, 1989). Ventilation expressed in terms of air change rate per hour (ACH) refers to the quantity of outdoor air divided by the building volume and is the rate at which the ventilation system dilutes and removes air contaminants present. Minimum exchange rates are typically 1.0 ACH of outside air and generally

Table 1: Recommended Ventilation Rates for Various School Rooms (Adapted From Bayer *et al.*, 1999; ASHRAE, 1989)

Room	Occupancy	CFM/person
Classroom	50	15
Multiple-Use Room	70	10-15
Laboratories	30	20
Craft Shops	30	20
Music Rooms	70	15
Gymnasiums	70	25-30
Libraries	20	20
Lounges	70	10-15
Offices	10	10-20
Lavatories	100	20-25
Locker Rooms	20	40-50
Cafeterias	100	15-20

correspond to 14-20% of outdoor air in the supply air (Baerg, 1993).

2.3.2 Temperature

2.3.2.1 Health Effects

While indoor temperatures are not normally associated with serious health concerns, correlation between warm temperatures and symptoms of SBS has been shown above 22.2°C (Hansen, 1999). High indoor temperatures may also be associated with dehydration and fatigue, while low indoor temperatures may cause minor physical discomfort such as chills. The most common complaint related to the thermal environment stems from localized thermal discomfort, where one part of the body is too cold or too hot. In general, however, maintaining a satisfactory temperature is largely a comfort rather than a health issue.

In addition to the effect of temperature on comfort, recent studies suggest that high temperatures may accelerate the off-gassing of volatile organic compounds (VOCs), such as formaldehyde that might, in turn, be associated with health effects (Maroni, 1995).

2.3.2.2 Standards

Indoor temperature guidelines vary according to season and units of clothing worn (CLO). For example, *Standard 55-1992, Thermal Environmental Conditions for*

Human Occupancy gives operative temperature recommendations of between 23-26°C in the summer and 20-24°C in the winter for light, mainly sedentary activity if the insulation of clothing is assumed to be 1 clo in winter and 0.5 clo in the summer (ASHRAE, 1992). OSHA offers similar recommendations, suggesting a temperature range of between 20°C to 24.4°C, depending on the season (OSHA, 1999). Table 2 outlines various the thermal insulation values of different clothing items.

Table 2: Thermal Insulation of Selected Garments (From Olesen, 2000)

Garment Description	Thermal Insulation (clo)
T-shirt	0.09
Short Sleeved Shirt	0.15
Normal shirt, long sleeves	0.25
Shorts	0.06
Normal Trousers	0.25
Light skirts (summer)	0.15
Heavy skirt (winter)	0.25
Thin sweater	0.20
Light summer jacket	0.25

2.3.3 Humidity

Relative humidity (RH) is defined as the ratio of the actual vapour pressure to the saturation vapour pressure (Bayer *et al.*, 1999). Increased RH and general dampness in an environment may be due to:

- Leakage of rain and snow into the building from ground moisture (outdoor sources).
- Moisture from humans and indoor activities (bathing, human expiration, humidifiers).
- Moisture within building materials from the erection time due to materials not protected against rain and snow (building sources).
- Water leakage (accidents).

2.3.3.1 Health Effects

In indoor environments, some level of humidity is necessary for comfort. However, the RH of indoor environments (over the range of normal indoor temperatures of approximately 19°C-27°C) has both direct and indirect effects on health and comfort. Direct effects results from the effect of RH on physiological processes, while indirect effects result from the impact of humidity on pathogenic organisms (Arundel *et al.*, 1986).

Both low and high RH may cause some physical discomfort. Air that is too dry (below 30% RH) has been associated with eye, nose and throat irritation, face rashes, discomfort for contact lens wearers, and frequent nosebleeds (Bayer *et al.*, 1999). One study linked RH of less than 40% with physiological effects leading to environmental discomfort and dissatisfaction (Bayer *et al.*, 1999). The mechanism behind respiratory discomfort is thought to be a weakening of the defense provided by the mucous membranes. RH in the winter, seen to be 40-50% lower in non-humidified than humidified schools, has even been implicated as a contributor to student absenteeism (Green, 1974).

Despite preliminary research ascribing respiratory health effects to low RH, there is little experimental evidence to indicate that the mucous membranes of healthy individuals are affected by low RH (Arundel *et al.*, 1986). In fact, other studies suggest that SBS symptoms such as dryness may be more strongly associated with indoor concentrations of VOCs (Hansen, 1999).

Too much airborne moisture may also have detrimental health effects. Humidities over 60% have been shown to contribute to thermal discomfort and heightened odor perception, and may exacerbate symptoms of people with asthma and allergies (Bayer *et al.*, 1999). Studies by Engvall *et al.* (2001) demonstrated an increased prevalence of respiratory symptoms among families living in damp homes. Furthermore, several UK studies have shown that humidified buildings have slightly higher rates of SBS than non-humidified buildings or those with natural ventilation (Engvall *et al.*, 2001). High RH also has an adverse direct effect on health when combined with high temperatures. Reduction in the rate of evaporative cooling of the body may lead to heat stroke, exhaustion and death (Arundel *et al.*, 1986). However, there is also evidence to suggest that respiratory illnesses decrease with increased humidity. The influenza virus is known to lose much of its virulence at 50% RH and certain organisms' mortality rates are highest at that level. Studies on airborne transmission of infective bacteria and viruses indicate that survival or infectivity of these organisms is minimized by exposure to RH between 40 to 70% (Arundel *et al.*, 1986).

In addition to problems directly associated with respiratory health and indirectly with bioaerosol growth, water vapor content in air can significantly affect the release rate of many indoor contaminants and their concentration in the air. Dry air fosters the breaking of fibers in air and other fabrics. Particles are suspended and recirculated for longer periods of time in dry air, increasing their likelihood of being inhaled. High RH levels are also thought to increase the off-gassing of VOCs, such as formaldehyde (Jennings, 1978).

2.3.3.2 Standards

Leading IAQ concerns for educational facilities include humidity control, particularly during cold months of the year. However, limited guidelines exist regarding the level of humidity. International standard 7730 (ISO, 1994) for moderate thermal environments gives no recommendations regarding humidity, while NIOSH recommends a range of humidities from 20% to 60% (NIOSH, 1987). In the ANSI/ASHRAE Standard 55-1992, acceptable humidity is given in terms of dew point temperatures (1.7 – 16.7°C). For an air temperature of 20°C, this would translate into a broad range of 30-81%. In most Canadian cities, indoor humidities range from 35% in the winter to 50% in the summer (Health Canada, 1995).

2.3.4 Mould

The Kingdom Fungi encompasses five main phyla: *Chytridiomycota, Zygomycota, Ascomycota, Basiodiomycota*, and *Deuteromycota* (Page and Trout, 2001). Characterized by a lack of chlorophyll, they include mushrooms, toadstools, yeasts, moulds, mildews, smuts and rusts. Because fungi comprise 25% of the earth's biomass, human exposure is unavoidable (Page and Trout, 2001). In indoor air, the fungi of interest are *Deuteromycetes*, known colloquially as "moulds". Moulds are thought to form colonies under particularly damp conditions when protected from direct sunlight and to spread spores under dry conditions. Many moulds ensure their survival by producing large quantities of spores in a short time (Miller, 1990). Spores of *Aspergillus* and *Penicillium* may remain viable for up to 12 years under favorable conditions (dry air at room temperature) (Miller, 1990).

While the majority of moulds produce spores for the purposes of dissemination, some are incapable of producing spores. *Mycelia Sterilia* is a form-order encompassing the filamentous moulds that remain sterile despite attempts to induce the formation of conidia or spores. Such an isolate is often termed "sterile mycelium", or simply "non-sporulating isolate". Strains grouped as "sterile mycelia" are not necessarily the same mould species, but share the inability to express diagnostic characters under the conditions provided (Sporometrics Inc., 2002).

Many moulds can produce mycotoxins, nonvolatile fungal metabolites with the potential to cause toxic reaction (Etkin, 1994). Production of mycotoxin may be caused by moisture content, temperature, aeration and stress factors (Page and Trout, 2001). In addition, mould growth is often recognized by the pungent odor that it produces, caused by the emission of certain VOCs (Etkin, 1994).

Major sources of spores include: handling of organic material, resuspension of spores by cleaning activity, and transport of spores on clothes and pets and by air currents (Reponen *et al.*, 1992). The most common leaf, or phylloplane moulds include *Cladosporium*, *Alternaria*, *Epicoccum* and *Aureobasidium*, making up between 40% and 80% of propagules in outdoor air (Miller, 1990). By contrast, soil-borne moulds such as *Aspergillus* and *Penicillium* make up less than a few percent of outdoor air samples (Miller, 1990). Buildings with IAQ problems tend to have high airborne concentrations of *Penicillium* species, while those with fewer complaints tend to have indoor air mould ecology similar to that of the outdoors. Common examples of moulds strongly associated with indoor proliferation in Canadian buildings are *Aspergillus versicolor*, *Aspergillus fumigatus*, *Aspergillus niger*, members of *Penicillium* subgenus Penicillium, and *Scopulariopsis* (Paracel Laboratories, 1988).

There is limited data on normal background levels of airborne moulds in school buildings. In a 1999 study of 631 schools in Atlantic Canada, the most common sites for mould contamination were classrooms and administration sites. Mould types and amounts were seen to vary with school construction type, school age, and composition and RH of the amplifying substrate material (Bayer *et al.*, 1999).

Moulds produce airborne propagules that vary in diameter from 2 µm to 100 µm with the smallest being single cells and the largest being multi-cellular (Miller, 1990). Examples of the dimensions of some common mould propagules are given in Table 3.

Airborne propagules may also vary in texture. Dry spores, like those of *Penicillium* or *Aspergillus* are easily disturbed and can become airborne, while wet and sticky spores, such as those of *Trichoderma* are produced in a slimy mess which is seldom airborne (Miller, 1990).

Table 3: Dimensions of Mould Spores (Paracel Laboratories, 1988)

Mould	Length (µm)	Width (µm)
Cladosporium cladosporiodides	3-9	2-4
Alternaria alternata	20-63	9-18
Paecilomyces varioti	2.5-3	5-7
Penicillium viridicatum	3	4

2.3.4.1 Health Effects

Recently, investigators have begun to identify microorganisms as the primary cause of symptoms in as many as 35%-50% of cases classified as SBS (Etkin, 1994; Chatigny, 1989). Microbial agents that have been implicated in IAQ-related health complaints include mould propagules, bacteria, protozoa, pollens and dust mites (Schillinger *et al.*, 1999).

Moulds may cause health problems in several ways. Firstly, infectious agents may penetrate the body's defenses, invading cells and colonizing tissues (Glenn, 1994). Among the facultative pathogens of interest are *Aspergillus fumigatus*, *Aspergillus terreus*, and *Aspergillus flavus*, all known to cause aspergillosis, an invasive lung disease (Miller, 1990). In general, it is immuno-compromised individuals who are susceptible to invasive disease, particularly from the mould *Fusarium* (Miller, 1990).

Secondly, allergenic moulds may cause acute reactions from stuffy noses to serious asthmatic attacks (Glenn, 1994). A Denmark study revealed that the prevalence of mould allergy in an atopic population was 8% in adults and 23% in children, 44% of the children having asthma and 23% rhinitis (Maroni, 1995). A Kansas study done by Su *et al.* (1992) examined the respiratory health problems experienced by children during the summer and winter seasons. In winter, hay fever was significantly correlated with indoor moulds, such as *Epicoccum*. Respiratory symptoms and wheezing and/or asthma complaints of school-age children showed a statistically significant association with indoor *Aspergillus* concentrations. However, no association was seen between bioaerosol characteristics and health effects in the summer sampling data.

Finally, moulds may also play a role in wider respiratory symptoms unrelated to allergies. Such mechanisms may involve inhalation of mould propagules and associated mycotoxins (Maroni, 1995). Mycotoxins are produced by a wide range of moulds and are found in the hyphae and spores, often being particularly concentrated in the latter. They are secondary metabolites, and when ingested are thought to cause illness and death (Maroni, 1995). Strains of the genus *Stachybotrys* are known to produce many bioactive and/or toxic compounds (Andersson *et al.*, 1997). Health complaints associated with *Stachybotrys atra* include central nervous system symptoms, respiratory tract symptoms, eye irritation, skin irritation, chronic fatigue and sinus problems (Etkin, 1994). However, research indicates that there is inadequate evidence supporting a causal relationship between symptoms of illness among building occupants and exposure to mycotoxins (Page and Trout, 2001).

Some moulds also produce a mixture of volatiles, responsible for a "mouldy smell" (Maroni, 1995). It has been demonstrated that while some people do not react to these volatile mixtures, others become nauseous and quite ill (Maroni, 1995). Table 4 lists some health effects of moulds.

The biological mechanism behind mould exposure and allergy is largely

Table 4: Health Effects Caused by Moulds (From ACGIH, 1989)

Organism	Causal Part	Disease
Histoplasma	Spores	Histoplasmosis
Penicillium species	VOC	Irritation
Aspergillus	Spores	Invasive aspergillosis; aspergilloma; allergic bronchopulmonary aspergillosis (ABPA)
All airborne mould spores	Spores	Allergic asthma, rhinitis
Stachybotrys atra	Toxin	Acute toxicosis

unknown, although several theories have been suggested. Most moulds produce proteins or glycoproteins that are antigenic. Such compounds may produce hypersensitivity diseases or allergies in susceptible individuals (Etkin, 1994). Mould allergies are thought to constitute 10-30% of allergies in the human population (Van Bronswijf *et al.*, 1986). For example, approximately 10-15% of the population is allergic to the moulds *Cladosporium* and *Alternaria* as determined by skin tests (Etkin, 1994). However, a study by Taskinen *et al.* (1997) demonstrated that skin test reactions to mould are rare in school children, at a percentage of only 5%, suggesting that allergies to mould are not yet developed at this age, becoming more common in adolescence.

2.3.4.2 Standards

Currently, there is an absence of standardized protocols for data collection, analysis, and interpretation (Rao and Burge, 1996). In general, existing quantitative standards for mould levels are based on baseline data due to a lack of information on human dose/response relationships for airborne moulds. Baseline data is commonly used to represent "normal" levels of indoor air propagules, and for comparison purposes with new data (Rao and Burge, 1996).

Appendix 1 demonstrates the mould standards and recommendations by a variety of regulatory agencies. According to the table, the ACGIH advises that indoor aerosol mould levels should be lower than those outdoors, but that quantities of up to 100 colony forming units (CFU/m^3) are generally acceptable. Agencies such as WHO and the Canadian Mortgage and Housing Corporation (CHMC) recommend further investigation of buildings where there is more than 50 CFU/m^3 of a single species (other than *Cladosporium* or *Alternaria*). A count of less than 150 CFU/m^3 with a mix of species is generally acceptable if no pathogens or toxigenic species are found. Counts up to 500 CFU/m^3 in the summer may be acceptable if primary species present are *Cladosporium* or other phylloplane mould. WHO and National Health and Welfare deem any indoor quantity of pathogenic or toxigenic mould (such as *Stachybotrys atra*) unacceptable.

Seasonal variations are important to consider when interpreting ratios of indoor to outdoor mould concentrations, since outdoor mould levels are strongly influenced by climate and weather. When there is snow on the ground, outdoor airborne mould levels will likely be quite low. Consequently, this may affect the penetration of mould particles into the indoor air, and the subsequent indoor to outdoor ratio.

2.4 Correlation Between Indoor Parameters and Mould Levels

In order for mould growth to occur on a surface, it must have a suitable temperature, a nutrient base and high RH, or an alternate source of moisture (Etkin, 1994). Furthermore, for propagation of mould, wind must act as a distributor of propagules. Consequently, a certain relationship might be expected between levels of indoor mould and comfort parameters and/or ventilation rate.

2.4.1 Nutrients and Mould Levels

Since moulds are heterotrophic, they cannot produce their own food and thus rely upon external nutrient sources (Etkin, 1994). Nutritive sources include any surface that contains a small amount of organic material (Etkin, 1994). As only a minute amount of carbon is required for mould growth, researchers have shown that mould can grow on surfaces such as glass, jet fuel, paint, rubber, textiles, and electrical equipment (Etkin, 1994). In fact, while fibreglass itself is incapable of supporting mould growth, the acrylic facings that maintain the physical integrity of the material may be nutritive surfaces (Etkin, 1994). In many cases, materials that are not easily degraded by mould may still be extensively colonized. In such cases, the mould may use the water and organic debris on the surface as a nutritive source (Bayer *et al.*, 1999).

Mould is also known to grow well on carpeted surfaces, largely due to high dust contents in carpets (Etkin, 1994) and ability for carpets to act as both reservoirs and amplifiers for mould. Floor dust from carpeted rooms frequently contains higher levels of *Penicillium*, *Cladosporium*, and *Aspergillus* (Etkin, 1994). *Stachybotrys atra* thrives on materials with a high cellulose content, such as wallpaper, gypsum board, pine panel, and insulating material at specific RH and temperatures (Etkin, 1994).

While this project did not investigate correlations between available nutrients and mould proliferation, it should be recognized that school environments typically provide acceptable media for mould growth.

2.4.2 Temperature and Mould Levels

Moulds exhibit different temperature requirements. Cryophilic (cold-loving) moulds may grow at less than 5°C while thermophilic (heat-loving) moulds thrive at temperatures as high as 55-60°C (Godish, 2001). Mesophilic, or mid-temperature moulds, the largest group, have an optimum temperature range of 20-30°C (Godish, 2001). Within these groups, each mould has a preferred temperature range. For example, *Pencillium* grows most readily between 20-25°C, while an optimal temperature for *Aspergillus* species is between 25-35°C. Some phylloplane moulds may even grow at temperatures below freezing, such as *Cladosporium*, seen to grow at temperatures as low as –6°C (Heinz Wilm, 2001). In general, however, an optimal temperature for most indoor mould growth is 10-35°C (Maroni, 1995).

2.4.3 Humidity and Mould Levels

2.4.3.1 Humidity and Visible Mould Levels

It is well recognized that a relationship exists between moisture problems and mould growth (Husman, 1996; Pirhonen *et al.*, 1996). At high humidities, when the dew point temperature reaches the temperature of a surface, condensation occurs. Condensation is the principal source of moisture needed for mould growth, whether superficial or interstitial, within porous materials such as concrete, brick and plaster (Maroni, 1995). A RH above 70% will permit condensation, providing moisture that can be adsorbed by materials with an affinity to water (Hansen, 1999). Damp surfaces then favor the growth of mould (Bornehag *et al.*, 2001). However, RH below 70% can also be problematic. If a wall or duct is cooler than the indoor air, the RH of the air surrounding that material will be higher, potentially high enough to become a source of moisture for hygroscopic materials (Hansen, 1999).

In general, RH levels of 25-70% promote mould growth on water-absorbing surfaces, while levels above 70% are ideal for spore germination and mould proliferation (Etkin, 1994). However, RH required for spore germination may vary with type of mould. Critical RH for hygroscopic growth of *Penicillium* spores lies between 37-73%, of *Aspergillus* spores between 12-42%, and of *Cladosporium* spores between 12-73% (Etkin, 1994). Nikulin *et al.* (1993) discovered that the minimum RH for growth of *Stachybotrys atra* is 78%-89%, and for toxin production, 84%-100%. It is also possible for mould growth to occur in building materials even when the RH of indoor air is considerably lower, if the RH of the materials is elevated (Husman, 1996). Investigators recommend that the RH of building materials (referred to as water activity) be kept below 75 - 80%. Table 5 indicates water activity (A_w) levels associated with various mould, where 1.0 A_w = 100% RH.

Table 5: Mould Associated with Varying Moisture Levels (From Husman, 1996)

Water Activity (A_w)	Microorganism
High (> 0.90 - 0.95)	*Aspergillus fumigatus*
	Trichoderma
	Exophiala
	Stachybotrys
	Phialophor
	Fusariuma
	Ulocladium
	Yeasts *(Rhodotorula)*
	Actinomycetes
Moderate (0.90 > A_w > 0.85)	*Aspergillus versicolor*
Lower (< 0.85)	*Eurotium*
	Wallemia
	Penicillia

While moisture in the substrate may be responsible for mould growth at some level, other studies demonstrate that atmospheric moisture is more effective than substrate moisture in bringing about germination of mould spores. In addition, the susceptibility of a material to mildew at a certain humidity is decided by the type of mould present (Block, 1953). For example, spores of *Penicillium chrysogenum* require a minimum RH for germination of 81% on glass and 72.8% on leather and other book materials. This may be due to a higher level of nutrient from the book cover than the glass. Table 6 demonstrates fluctuating mould growth dependent on both media and percent RH.

Table 6: Mould Growth with Varying Media and Humidity (Adapted From Block, 1953)

Material	Percent Humidity (%)						
	100	96	92	88	85	80	76
Leather	5	5	5	5	4	4	4
Cheese	5	5	5	5	5	2	1
Wood	5	5	4	4	3	0	0
Glass Wool	5	2	0	0	0	0	0

Visual scale of mould growth: 0-None, T-Trace, 1-Very light, 2-Light, 3-Extensive, 4-Heavy, 5-Very Heavy

In general, colonization is not observed at RH below 70% (Price *et al.*, 1995). However, even in dry environments, studies have shown that buildings with RH below 60% in winter and summer values not exceeding 80% may be inhabited by xerophilic moulds, organisms that have low water requirements (Price *et al.*, 1995).

2.4.3.2 Humidity and Airborne Mould Levels

Once moulds are established on a surface, they ensure their survival by producing large quantities of spores in a short time (Miller, 1990). Mass production is essential since it is estimated that only 1-25% of mould spores are viable. Furthermore, spores may disseminate in air differently, depending on size and moisture content of the air. (Tobin *et al.*, 1987). Dry spores, such as those of *Aspergillus* or *Penicillium*, easily become airborne. Spores contained in slime, such as those of *Stachybotrys atra* and *Fusarium*, are produced in a wet mass that seldom becomes airborne (Etkin, 1994). Once released, spores of *Aspergillus* and *Penicillium* may remain viable for up to 12 years under favorable conditions (Miller, 1990). It is well known that mould mycelium does not sporulate or release spores continuously; release is thought to depend largely on moisture content of the air. Jantunen *et al.* (1987) demonstrated how increasing indoor air RH from 18-40% to 38-62% by humidification significantly decreased airborne mould spore levels. In a 1991 study, Pasanen *et al.* (1991) demonstrated that spore release might be dependent on mould genus and controlled by external factors such as RH and air speed. *Aspergillus* and *Penicillium* released more spores into dry air (RH <42%) and less spores into moist air (RH >70%), while the effect of RH on the release of *Cladosporium* sp. spores was ambivalent, possibly due to the bigger spore size. Results from the study are presented in Table 7.

Dissemination of mould spores may also occur as acute events, known as "fungal burst events" whereby transient clouds of airborne spores are generated by activities such as vacuuming, demolition and maintenance (Etkin, 1994). Fungal bursts may be more common in the winter, when air-handling units are operating on a more consistent basis. A recent study concluded that a combination of lower RH and inefficient ventilation, particularly in the winter season, contributed to the spread of airborne microbes (Bayer *et al.*, 1999).

Table 7: Effect of Relative Humidity on Spore Release (Pasanen *et al.*, 1991).

Velocity (m/s)	Relative Humidity (%)	Spore Count (CFU/m^3)		
		A. fumigatus	***Penicillium* sp.**	***Cladosporium* sp.**
0.5	12-18	100	600	<25
0.5	37-42	200	100	<25
0.5	71-73	<25	400	<25
1.0	12-18	700	1800	25
1.0	37-42	500	16000	<10
1.0	71-73	200	400	<10
1.5	12-18	1000	52100	25
1.5	37-42	2600	1900	<10
1.5	71-73	200	1100	200

2.4.4 Ventilation and Mould Levels

Literature indicates that the rate of removal of airborne pathogens relies on the air change rate (ACH) and ventilation effectiveness (or degree of air mixing). A study of indoor *Aspergillus versicolor* by Wurtz *et al.* (1999) suggested that ACH (p=0.06) had a tendency to be associated with concentration of airborne mould ($r^2 = 0.4$). The dilution principle suggests that the concentration of an indoor pollutant is inversely proportional to ventilation rate. Ideally, if plug flow (piston flow) is assumed in a room, then one air change would completely remove all pathogens that were initially present (Kowalski and Bahnfleth, 1998). However, outside of a controlled environment, this rarely occurs. Instead, complete air mixing has been shown to delay removal of airborne pathogens in an exponential manner (Kowalski and Bahnfleth, 1998). Furthermore, the dilution principle may not be applicable to biological agents such as *Cladosporium*, which is more likely to be concentrated outdoors than indoors. With increases in ACH, indoor levels of *Cladosporium* would be expected to increase, not decrease. As with the majority of contaminants, it is the source strength that will determine airborne mould levels found indoors (Fanger, 1989).

Figure 1 illustrates the purging effect of varying ACH, assuming that outside air is free of contaminants. However, the actual amount of outdoor air that can be economically brought in to a building will depend on ambient conditions. In colder climates, minimal ACH is often dictated by high energy costs (Kowalski and Bahnfleth, 1998).

Recent ventilation studies have reported below-standard ACH in buildings (Smedje *et al.*, 1997) Under these conditions, indoor concentrations of spores and dust-borne microorganisms may be elevated (Dybendal and Elsayed, 1994). Furthermore, even the most delicate of air currents can cause mould spores to become airborne. Moulds such as *Aspergillus* and *Penicillium* will produce their spores on stems that project above the surface to take advantage of passive dispersal (University of Toronto, 2002).

In addition to ACH effects on spore levels in air, ventilation systems provide an ideal environment for microbial growth and airborne distribution including humidifiers, filters and outdoor air intakes. Mould common to ventilation systems are

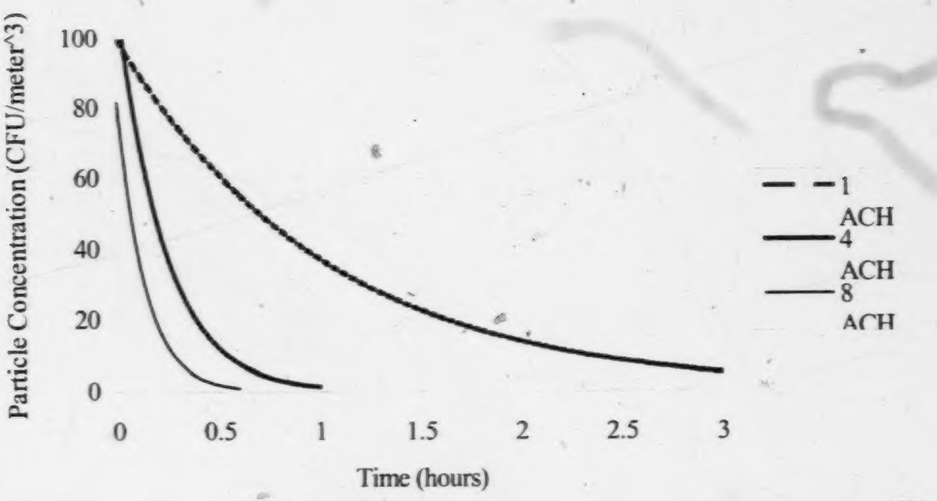


Figure 1: Effect of Outside Air Purge on Initial Contaminant Levels (Kowalski and Bahnfleth, 1998)

Absidia, *Acremonium*, *Alternaria*, *Aspergillus*, *Aureobasidium*, *Botrytis*, *Cephalosporium*, *Cladosporium*, *Mucor* and others (Boss and Day, 2001). For microorganisms to be a problem, they need to be disseminated into the air and inhaled. Consequently, HVAC systems are a major cause of microbial amplification and distribution (Hansen, 1999).

2.4.5 Occupancy and Mould Levels

Previous studies indicate that there are indoor sources of airborne mould spores, largely everyday activities (Reponen *et al.*, 1992). As a result, occupant density is thought to be an important contributor to indoor bioaerosol problems (Burge, 1995). In a Denmark study of microflora in schools, researchers found that significant parameters for predicting airborne mould concentrations included area per person (Bayer *et al.*, 1999). High occupant densities, such as those in schools, are thought to result in an increased release of moisture into room air, ultimately encouraging mould growth (Bayer *et al.*, 1999). Furthermore, virtually any human activity can increase airborne microbial loads. Resuspension of mould particulates may occur as a consequence of occupant activity including children playing and movement of objects.

Differences in size and sedimentation rate of spores may also affect what is detected in air. Studies have shown that large *Ulocladium* spores from mould patches on walls settle rapidly so that spores are only airborne for short periods of time (Van Bronswijk *et al.*, 1986).

2.4.6 Indoor and Outdoor Mould Levels

Infiltration of mould spores may influence indoor levels. A residence with open doors and windows with heavy foot traffic will average 95% of the outdoor mould concentration while high-rise office buildings with little air exchange may average 2%. In addition, dusty interiors may exceed 100% of the outdoors to some degree, but will still mirror the outdoor distribution of spore types (Environmental Microbiological Laboratory Inc., 2001). While the type and quantity of outdoor moulds will have an impact on indoor mycoflora composition, significant differences may also exist between indoor and outdoor moulds. Differences may be most pronounced when studies are conducted in the winter. During this season, there is limited intrusion of outdoor mould into indoor spaces. Common outdoor mould includes *Cladosporium*, *Alternaria* and *Epicoccum*. Outdoor concentrations will vary from non-detectable (under cold, snow-covered conditions) to tens of thousands, often during autumn when harvesting is under way. With the exception of winter, outdoor mould levels are almost always higher than those measured indoor (Environmental Microbiological Laboratory Inc., 2001).

2.5 Perception of IAQ Parameters

2.5.1 Introduction to Perception

Complaints concerning poor IAQ are becoming increasingly common. These grievances frequently precipitate exhaustive building investigations and discussions concerning the medical relevance of IAQ. If the validity of occupant complaints could be established, extensive and often expensive building investigations could be reduced.

In studying perceptions, it is imperative to differentiate between physical perceptions and environmental perceptions. Physical perceptions emerge due to internal physiological stimulation whereas environmental perceptions arise from external sensory stimulation. Physical perceptions include dry skin or eye irritation while environmental perceptions include sensations of draught or odour (Maroni, 1995). Humans perceive air by two senses. The olfactory sense situated in the nasal cavity is sensitive to several hundred thousand odorants in the air. The general chemical sense is situated all over the mucous membranes in the nose and eyes and is sensitive to a similarly large number of irritants in the air (Quine, 1990). It is thought that the combined response of these two senses determines whether the air is perceived fresh or stale, stuffy and irritating. People with normal functioning body senses should perceive the same things in the environment (such as odors, visual objects), acquired through perceptual learning processes (Quine, 1990). Consequently, it is thought to be easier to establish a dose-response relationship for environmental perceptions than for body perceptions (Maroni, 1995).

Recent studies suggest that human perception may be a reliable indicator of comfort and health effects. In a study by Engvall *et al.* (2001), perceptions of mouldy odour and high air humidity were found to be significantly related to an increased occurrence of SBS symptoms, even when adjusted for confounding by age, gender, population density and building-related risk factors. In an investigation of subjective IAQ in 14 Swedish schools, Norback (1995) reported a relationship between perception of poor IAQ and high room temperature. However, while there is evidence to suggest that human perception may reflect environmental parameters, results are by no means conclusive. Furthermore, environmental and personal confounding factors may obscure relationships between perception and parameter measurement.

Although experimental evidence has not yet concluded that perception is a valid indicator of environmental parameters, agencies have started to incorporate perception into definitions of acceptable air quality. ASHRAE defines adequate IAQ as:

> "Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction" (As quoted in Haghighat *et al.*, 1992).

Consequently, evaluating the reliability of perception as an environmental indicator is a valid investigation.

2.5.2 Confounding Factors

Models for relating human perception of IAQ with actual measurements of IAQ parameters can be influenced by a wide array of confounding factors. Some of these include environmental confounders (location of office, carpet in office) (Nelson *et al.*, 1991).

However, more and more studies are indicating that perception of IAQ and SBS reporting may be more strongly related to person-related factors than to environmental factors. Some of the individual factors that may contribute to occupant response include: gender, age, education, allergy status, antihistamine/cortisone medication, smoking, and hours spent in building/week. Worry, anxiety and depression are components of negative affectivity and have also been found to be associated with SBS symptom reports (Bauer *et al.*, 1992). Increasing evidence in the literature suggests that negative-affectivity may be strongly related with self-reports of somatic symptoms, distress and dissatisfaction (Watson and Pennebaker, 1989).

2.5.3 Perception and Humidity

Pervious studies have shown that air temperature and humidity influence perceived quality of indoor air (Kerka and Humphreys 1956; Berglund and Cain, 1989). However, while one study found that increasing humidification to 30-40% RH in an office building reduced complaints of dryness, others have indicated that the sensation of "dryness" may not be related to physical humidity levels but may be due to high temperatures, ventilation rate or airborne contaminants (Fang *et al.*, 1999). Other risk variables thought to be related to the perception of dry air include age of the building, electric heating and condensation of moisture on the windows during winter (Andersson *et al.*, 1995).

While studies have not yet demonstrated a correlation between measured and perceived air humidity, rooms are often described as "stale" or heavy at high RH (Berglund and Cain, 1989). The sensation of stuffiness may be due to decreased cooling of the mucous membranes in the upper respiratory tract. Odors may also be perceived as more intense at higher humidities. In one study, perception of unpleasant odor and stuffiness increased when the air was humidified to 40% (Reinikainen, 1993). While nonhumidified air (20-30% RH) was considered acceptable by 90.6% of panelists, only 76.4% of panelists considered humidified air (30-40% RH) to be acceptable. In general, air quality is considered to be unacceptable at RH above 50% (Reinikainen, 1993; Berglund and Cain, 1989).

A study by Haghighat and Donnini (1999) illustrated differing perceptions of humidity by males and females (Figure 2).

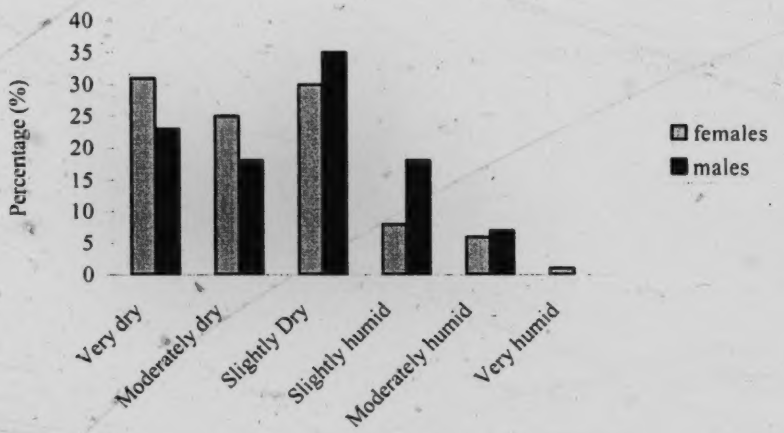


Figure 2: Ratings of Overall Office Humidity By Gender (Haghighat and Donnini, 1999).

As indicated, male respondents tended to feel that the air was humid where females described the air as dry. Figure 2 illustrates the role of gender as a confounding factor, and its potential to overshadow overall trends between perception and parameter measurement.

2.5.4 Perception and Temperature

Perception of heat is related to a person's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures (ASHRAE, 1992). Heat transfer from body to environment may be influenced by temperature, humidity, air movement, personal activities and clothing.

A study done by Reinikainen and Jaakkola (1993) evaluated the effect of room temperature on the perception of IAQ. Results from the study indicated a statistically significant linear increase in sensation dryness with temperatures in the range from 21°C – 25°C (Table 8).

In this study, temperatures above 23°C were found to be a significant risk factor for the continuous sensation of dryness. A Danish study conducted in 1985 also suggested that higher temperatures (21-26°C) were associated with mucosal irritation and negative perceptions of air quality (Skov, 1990). However, the perception of dryness might also be enhanced by an increase in release of volatile pollutants from building materials and a decrease in RH at higher temperatures, both intensifying mucosal desiccation (Reinikainen, 1993; Maroni, 1995).

Table 8: Effect of Temperature on Sensation of Dryness (Jaakkola and Heinonen, 1989)

	Temperature °C									
Sensation of Dryness	≤22		>22≤23		>23 ≤24		>24		Total	
	n	%	n	%	n	%	n	%	n	%
Satisfied	8	25.8	23	22.3	24	16.8	3	5.8	58	17.6
Sometimes dry	17	54.8	41	39.8	51	35.7	18	34.6	125	38.6
Always dry	6	19.4	39	37.9	68	47.5	31	59.6	144	43.8
Total	31		103		143		52		329	

High indoor temperatures are also thought to be related to the perception of stuffiness (Jaaakkola and Heinonen, 1989; Skov, 1990). In a Berglund and Cain (1989) study, air was considered to be less stuffy and fresher with decreasing temperature and humidity. However, the effect of temperature on the perception of stuffiness was seen to be linear and more dramatic than the effect of humidity.

2.5.5 Perception and Ventilation

Ventilation is essential in order to maintain a comfortable and healthy indoor environment. In practice, comfort generally determines ventilation rate, although ASHRAE standard 62-1989 gives a ventilation requirement for office spaces as approximately 20 cfm/person (ASHRAE, 1989). Past research indicates that ventilation rates at or below 20 cfm/person are associated with an increased prevalence of SBS symptoms (Mendell, 1993; Godish and Spengler, 1996). A study by Wargocki *et al.* (2000) examined perceived air quality, SBS symptoms and productivity in a normally furnished office space ventilated with an outdoor airflow of 6, 20 or 60 cfm/person. Temperature and humidity were kept stable at 22°C and 40% respectively. Results from the study indicated that increasing ventilation improved the percentage of subjects satisfied with the air quality & increased perceived freshness of air. Past laboratory and field studies have indicated that ventilation rate has historically been a method of improving perceived quality of indoor air and particularly in the reduction of perceived stuffiness. A 1993 study also demonstrated a significant association between ventilation rates and reduced prevalence of SBS symptoms in schools (Godish and Spengler, 1996).

Other studies have not noticed an association between increased ventilation rate and diminished stuffiness (Menzies *et al.*, 1991). Rather, an increased airflow may actually promote increased emission of pollutants that may reduce or even reverse positive effects of increased outdoor air supply. Similarly, heightened sensations of dryness might be due to increased concentrations of pollutants that may accompany higher ventilation rates.

2.5.6 Perception and Mould

Mouldy odour is often used as an indicator of microbial growth. In damp buildings, microbes may produce VOCs. These have been detected as "mouldy smells" in several studies of "sick buildings" (Tobin *et al.*, 1987). However, perception of odour may also be modified by personal factors and a composition of odorous mixtures (Cain and Cometto-Muniz 1993).

While many studies indicate that perception of mustiness and evidence of airborne mould are not related, it should be noted that no one sampling technique is adequate for assessment of airborne mould levels (Van Bronswijk *et al.*, 1986). Different samplers, variable media and variation of propagule counts over time and space may impact qualification and quantification of airborne mould samples.

2.6 Summary of Literature

IAQ has been an emerging topic of the last half-century. While investigations originally focused on infiltration of outdoor pollutants, current research examines indoor sources of contaminants, and related health concerns. The effect of IAQ on school-aged children is an area of particular interest due to the immaturity of a child's immune system coupled with the lengthy period of time that a child spends at school. Recent studies suggest that IAQ problems in schools may compromise a child's health and performance (Koskinen *et al.*, 1993).

To date, a plethora of indoor contaminants have been identified. From these, studies have highlighted ventilation, RH and temperature as important indoor comfort parameters. Recent investigations have also linked incidents of mould contamination with respiratory ailments and other symptoms of SBS. Investigation of the interplay of comfort parameters and airborne mould levels suggests that, in general, higher humidity levels and a specific temperature range precipitate mould growth, while lower RH encourages dissemination of mould propagules. In addition, ventilation is thought to assist in the circulation of mould spores. Other contributors to indoor airborne mould levels may include outdoor mould levels and occupancy rates. Indoor airborne particulate levels will generally reflect outdoor levels, leading to higher indoor levels in the summer months and lower levels in the winter months. Airborne particulate concentrations are expected to increase linearly with occupancy levels.

In addition to evaluating the relationship between comfort parameters and airborne mould levels, another method of predicting bioaerosol contamination might be evaluating environmental perception of building occupants. While the correlation between symptomatology and indoor air parameters has been analyzed before, human perception is subject to a spate of confounding factors, including age, gender and health status. Consequently, past studies have highlighted the inconsistencies of perception studies, particularly in an uncontrolled environment. Studies relate descriptions of human perception of the indoor environment, using terminology such as "dry", "stuffy", "humid", "hot", "cold" and "musty" with varying levels of indoor environmental parameters. For example, in one study, "dry" may appear to correlate with elevated temperatures, while in another, "dry" appears to be based on RH. While no clear trend is evident between human perception and environmental parameters at this time, ongoing research into possible associations is worthwhile.

3.0 APPROVAL OF RESEARCH BY HEALTH RESEARCH ETHICS BOARD

The Health Research Ethics Board (HREB) is an organization dedicated to improving the ethics review process for Edmonton-area researchers. Board members represent the University of Alberta, the CHA and the Caritas Health Group (HREB, 2002). The group has collective expertise in a wide range of research methodologies, clinical and education specialties, and is knowledgeable in research and practice ethics. The Board consists of two panels: Panel A reviews and approves biomedical (invasive) research studies, while Panel B appraises health research (non-invasive) investigations.

In order to proceed with research, investigators completed an *HREB Request for Ethics Review* form (Appendix 2) and submitted it, along with the research proposal to HREB Panel B in June 2001. Following receipt of the documentation, HREB advised investigators of a July 6 ethics review meeting date. At this meeting, researchers provided a brief overview of the project, and answered questions from the HREB. Following discussion of the nature of the project, the board determined that an ethics review was unnecessary. A copy of this correspondence is provided in Appendix 3.

4.0 MATERIALS & METHODS

4.1 Sampling Design

4.1.1 Selection of Participants

School boards within the CHA's jurisdiction were invited to participate in an investigation of IAQ. Boards from Edmonton Public Schools (EPS), Elk Island Public Schools (EIPS) and Elk Island Catholic Schools (EICS) elected to become involved in the study, comprising a population of 217 schools. Of these, 20%, or approximately 43 schools were randomly selected for participation. As confirmed with a statistician, a sample size of between 10-20% of a total population of this size will accommodate design constraints while still permitting standard distribution and parametric statistical analysis (Jhangri, 2001).

For each school board, a proportional number of schools were allotted to participate. For example, out of 217 schools, 189 were EPS, 20 were EIPS and 8 were EICS. A complete list of schools is given in Appendix 4. Proportionally, for a sample size of 43, 37 (87%) would come from EPS, 4 (9%) would come from EIPS and 2 (4%) would come from EICS. However, due to restrictions in resources within EPS, some adjustments were made to these proportions. Ultimately, 32 EPS, 7 EIPS and 4 EICS were sampled. Schools selected for participation in the study are included in Appendix 5.

In order to ensure that a sample size of 43 was met, an extra 10 schools were randomly selected in a proportional manner from the school boards. This accounted for the possibility that some principals might decline to participate in the study.

4.1.2 Demographics of Population

Edmonton proper has an approximate area of 670 km^2 (Economic Development Edmonton, 2001). Within this area, Alberta Infrastructure clusters EPS into nine wards according to Figure 3.

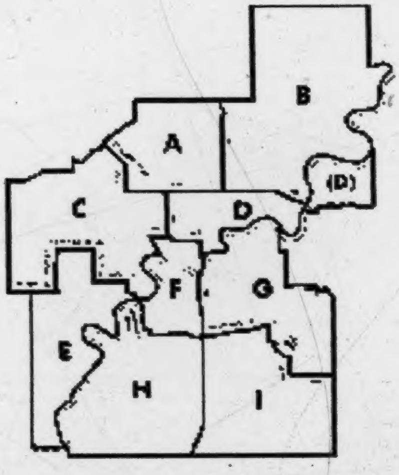


Figure 3: Edmonton Public School Wards (EPSB, 2001)

Each ward contains between 16 to 22 schools and is made up of elementary, junior high and high schools. EIPS and EICS group schools by region. For example, EIPS encompasses schools in Sherwood Park, Strathcona County, Lamont, Fort Saskatchewan and Vegreville. EICS has schools in Sherwood Park, Ardrossan, Fort Saskatchewan, Camrose and Vegreville. Some of these communities are greater than 30 minutes of travel time from the city of Edmonton. Therefore, to minimize the travel time of investigators, only schools from Edmonton, Sherwood Park and the surrounding parts of Strathcona County were included in the study.

To compile background information on each of the schools within the study population, investigators distributed *Pre-Screening Surveys* (Appendix 10) to facilities personnel in EPS, EIPS and EICS. Information collected included level of schooling, utilization rate, initial construction date, type of foundation and history of water damage or mould investigation. Complete results from this survey are given in Appendix 11. Statistical summaries of results are given in Figures 4 to 7 and Figure 10.

EPS, EIPS and EICS accommodate Grades 1-12. Schools are classified as elementary (Grades 1-6), junior high (Grades 7-9), high school (Grades 10-12) or a combination thereof. Figure 4 indicates the proportion of schools by level of schooling for the 217 schools in the study.

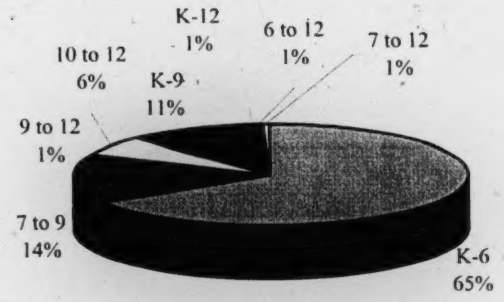


Figure 4: Level of Schooling in the Study Population

Figure 4 illustrates that 65% of the study population are elementary schools, 14% are junior high, and 6% are high schools. Combinations of elementary, junior high and high school account for the remaining 15%.

Alberta Infrastructure defines utilization rate as "the ratio determined by dividing school's total full-time student enrollment by its net capacity" (Alberta Infrastructure, 2002). Figure 5 indicates that 30% of the study population has a utilization rate of between 60-80%, while 26% are utilized between 40-60%, and 24% have a utilization rate of 80-100%. Thirteen percent of the study population has a utilization rate of more than 100%, while only 1% has a rate of less than 20%.

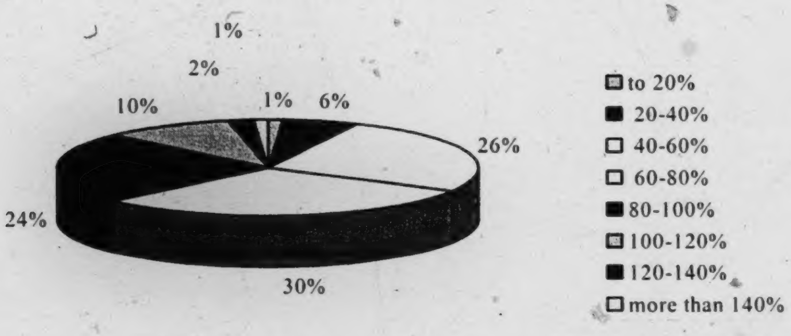


Figure 5: Percentage of Schools by Utilization Rate in the Study Population

Initial construction of schools in the study population occurred from 1905 to 1998. Within this range, 36% of the schools were built between 1941-1960, and another 42% were built between 1961-1980, during the time when "tight" buildings were constructed to limit energy expenditures. Figure 6 indicates that 13% of schools were built between 1981-2000, while only 9% were built prior to 1941.

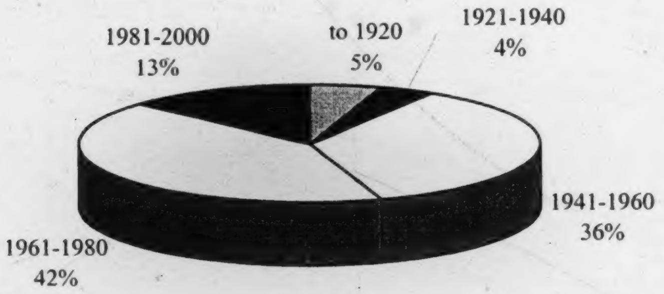


Figure 6: Initial Construction Date of Schools in the Study Population

IAQ is thought to be directly related to a building's construction and foundation materials. Materials selected for a building may either limit or support the growth of microbes, and can influence other indoor air parameters such as RH. Significant mould growth has been associated with soil in crawlspaces due to wet surfaces and high RH (Godish, 2001). Similarly, basements that serve as utility areas for forced air heating have been associated with elevated airborne mould concentrations. Furthermore, buildings constructed on slabs or crawlspaces may result in high, localized RH that may cause condensation (Godish, 2001).

All of the foundations of the schools in the study population were either slab-on-grade, crawl-space, basement or combinations thereof. Figure 7 outlines the proportion of schools with each type of foundation.

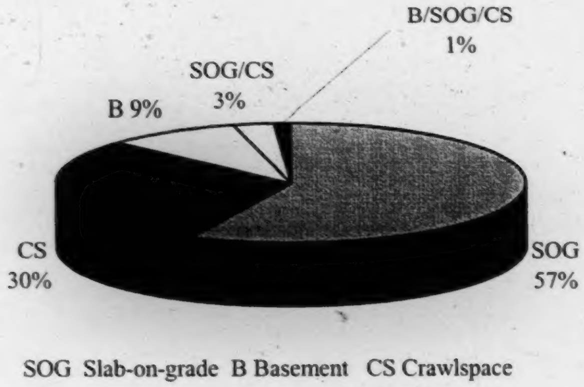


Figure 7: Foundation Material of Schools in the Study Population

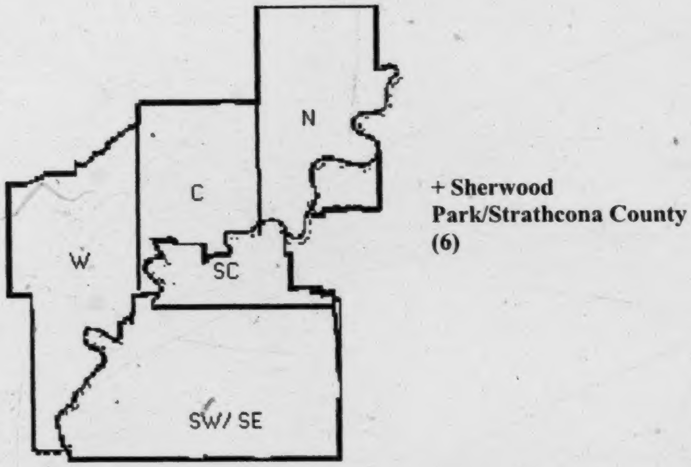
Because participant schools varied in many respects including level of schooling, utilization rate, date of construction and construction material, a certain amount of bias could not be eliminated from the study. However, influence of these factors was minimized through use of a randomized sampling design.

4.1.3 Selection of Schools

Stratification is a random sampling technique whereby the whole population is first divided into mutually exclusive subgroups or strata (EPA, 1983). The segments are based on some predetermined criteria such as geogra[illegible]ocation, size or demographic characteristic and are intrinsically homogenou[illegible] purpose of stratified sampling is to identify significant sub-populations that [illegible]ist in the larger population, and to proportionally represent these sub-groups in the final sample. In theory, the more homogeneous the group, the greater the precision of the sample estimate (EPA, 1983).

Possible strata that were identified in the population of interest included geography, utilization rate, grade-level, age of school and foundation material. Because the study involved school boards from Edmonton and the Elk Island region, stratifying the population geographically seemed prudent in order to ensure proportional representation from each school district.

The entire population of schools in Edmonton is divided into nine geographic zones, based on Alberta Infrastructure specifications. The study population further included EIPS and EICS from Sherwood Park and Strathcona County. To have approximately equal numbers of schools in each geographic grouping, the three school boards were divided into six zones according to Figure 8.



N North C Central W West SC South Central SW/SE Southwest/Southeast

Figure 8: Adjusted Alberta Infrastructure Geographical Zones Used for First Level of Stratification (Adapted from EPSB, 2001).

Each zone was intended to contain a similar number of schools, as illustrated in Figure 9.

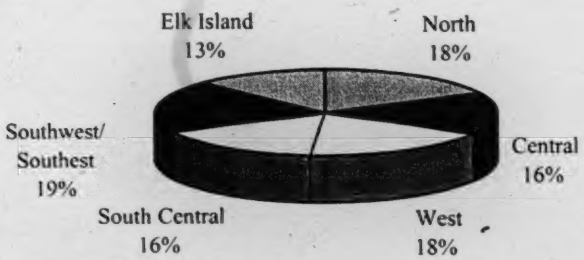
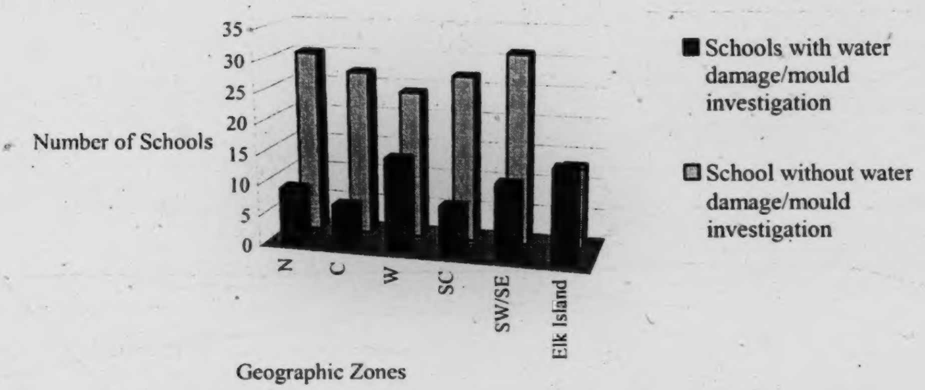


Figure 9: Percentage of Total Schools Per Region

Second-level stratification allowed further specification of schools to be studied. Schools were grouped according to whether they had or had not experienced significant water or mould problems within the last five years. Inclusion of this strata into the design ensured that schools with backgrounds of mould and water damage were identified and proportionally represented. Figure 10 indicates the number of schools per region with or without water damage or mould investigation.



N North C Central W West SC South Central SW/SE Southwest/Southeast

Figure 10: Number of Schools Per Region With or Without Previous Water Damage and/or Mould Investigation

A proportional number of schools were then allotted to each stratified category for a total of 43. Due to resource limitations, slightly skewed proportionality replaced true values. Subsequently, 32 EPS, 7 EIPS, and 4 EICS were selected. Appendix 6 indicates approximately proportional allocation of 43 schools into two-level strata.

Level of schooling, utilization rate, foundation material, and age of school were also considered as possible strata. However, statistical analysis demonstrated that use of these strata would result in disproportional numbers of schools in some categories (Appendix 7).

The schools to be sampled were randomly selected from the categories resulting from two-level stratification. The number of schools selected from each category was proportional to the number of schools in each category.

Within the schools, between three to seven classrooms were randomly selected for the study. A classroom was defined as a structure that is occupied and in use as a lecture facility. This definition excluded structures that would be described as laboratories, offices, gymnasiums, bathrooms etc. Exclusion of these structures was intended to prevent the introduction of cofounders that would introduce additional bias to the study.

4.1.4 Subsets

To further minimize bias, a group of six subsets was established. Schools randomly selected for each subset are listed in Appendix 8. The purpose of each subset was either to assess the extent of variability that existed under certain conditions, or to satisfy time restrictions for completing the study. The subsets were:

- Between structures
- Within structures
- Within space
- Seasonally
- Between instruments used to measure ventilation rates
- Carbon dioxide decay

To satisfy time constraints, eight to ten schools were assigned to each subset. Within each subset, between three and five classrooms were sampled.

4.1.4.1 Between Structures

The subset to study "between structure variability" consisted of nine schools. The intent of the subset was to assess differences in IAQ parameters between structures. For the purposes of the study a "structure" was defined as either a permanent, portable or pod building. Alberta Infrastructure (2002) defines a permanent structure as one that "does not include portable units". A portable is defined as "a facility constructed for relocation from site to site and installed without physical connection to a facility of permanent construction" (Alberta Infrastructure, 2002). Finally, a pod is classified as "a core portable classroom attached to a school" (Wilson, 2002).

To select the subset, schools with at least two structure types were identified. Schools within this group were numbered, and nine were selected using a random number chart with numbers from 00-99 (Zar, 1974). Within these schools, two classrooms were randomly selected in each structure type. For those schools with multiple structures of one type, one was randomly chosen. Up to five classrooms in a school could be sampled if a school contained a permanent, pod and portable structure.

4.1.4.2 Within Structures

Classrooms in a permanent or pod structure may differ from each other in terms of size, shape, purpose and occupancy. To assess variability of IAQ parameters within a structure-type, samples of parameters from multiple classrooms in one structure were compared. Because portables consist of a single classroom, they were not included in this subset.

Eight schools were selected to participate in this subset. From the entire sample of schools, four were selected with permanent structures and four were selected with pod structures. Once a school was selected as part of a pod or permanent group, it was replaced in the pool. As a result, schools might be randomly selected to be part of more than one category. For instance, a school might be originally selected for investigation of within pod variability, and then randomly selected for investigation of within permanent variability, provided that it had each structure. Three classrooms were randomly selected for investigation in each structure. In this way, up to six classrooms might be investigated in each school.

4.1.4.3 Within Space

Location of a contaminant source is thought to determine spatial distribution of contaminants within a room (Mage, 1996). Heterogeneity of concentrations may be due to placement of fans, location and discharge characteristics of supply inlets, location of return or exhaust air outlets, internal barriers to airflow and thermal gradients in the room (Mage, 1996).

To assess variability of air quality parameters within a space, samples were taken at three locations around a classroom, determined according to the *Sampling Protocol* (Appendix 9). For this subset, at least three classrooms were sampled per school, the default number of sampled classrooms. However, if the school had been assigned to the between structure or within structure subset, more classrooms would be sampled.

4.1.4.4 Seasonality

Seasonal variations are thought to be significant with regards to IAQ. Parameters such as temperature, humidity, and microbial concentrations may vary significantly with season. Levels of temperature, humidity and microbes are known to be lowest in winter while microbes are thought to be at their highest level in the summertime (Godish, 2001). Since outdoor levels of environmental parameters are known to influence indoor levels, it can be inferred that significant differences in indoor air parameters will exist seasonally. It should be noted, however, that earlier studies have stated that moulds such as *Penicillium* spp. in indoor air do not follow outdoor seasonal periodicities and are generally regarded as indoor mould (Wurtz *et al.*, 1999).

To accommodate the time parameters of the study, winter and fall were eventually selected for sampling phases. Growth of mould in the winter was anticipated to be virtually nonexistent, and low levels of humidity and temperature were expected. By contrast, a fall sampling round was thought to provide an opportunity to witness significantly higher levels of indoor/outdoor spore levels. Sampling during summer was not considered because classrooms would be unoccupied for the majority of the season. Originally, spring was considered for the second sampling phase. However, because of the cold climate of Alberta and expected late arrival of spring, winter was thought to be a more suitable sampling period based on the duration of the season. Furthermore, separation of the sampling period into three phases was eventually discounted based on inherent statistical difficulties in analyzing a three-way design (Prasad, 2001).

Study of seasonal variability required two visits to the same school and classrooms, one in the fall and one in the winter. In addition to inclusion in the seasonality subset, schools might also be part of any of the other subsets.

4.1.4.5 Evaluation of Airflow Monitor

The purpose of this subset was to evaluate the performance of an airflow instrument. Measurements from an Alnor Standard Balometer® (Texas Scientific Instruments, Shoreview, MN) were compared with those obtained with a Velocicalc Plus® (Texas Scientific Instruments, Shoreview, MN). The intent was to compare data from the Velocicalc Plus® using a standard, previously validated instrument in order to accurately determine ventilation rate. However, subsequent comparison between instruments was limited by several factors. Because the Alnor Standard Balometer® was equipped to measure airflow from 2'x 2' diffusers only, it could not be used in all schools. Furthermore, the instrument was on loan for a two-week duration. Consequently, the subset was limited to supply diffusers from eight schools.

4.1.4.6 Carbon Dioxide Decay

The Q-Trak® (Texas Scientific Instruments, Shoreview, MN) instrument was used to monitor decay of carbon dioxide over a 24-hour timeframe. Ventilation rates calculated from carbon dioxide decay data were compared with those calculated from Velocicalc Plus® measurements. Ten schools were included in this subset.

4.1.5 Participant Recruitment

Prior to the inclusion of student investigators, CHA invited school boards to participate in the study. School boards that elected to participate were then asked to prepare *Pre-Screening Surveys* (Appendix 10) for each of the schools in their jurisdiction. The purpose of this was to prepare criteria for stratification and subsequent selection of schools.

Before sampling, investigators sought the consent of the principles from each school. This involved distribution of information to each randomly selected school. In addition to the 43 schools selected for the study, packages were also disseminated to ten extra schools to ensure an ultimate sample size of 43. Furthermore, ten principals were invited to participate in the seasonal study, requiring a visit in fall 2001 and winter 2002.

The information package included an *Introductory Letter*, *Information Letter*, *Response/Consent Form*, and *Conduct Protocol*. Packages were distributed to EPS and EICS via a board representative, and hand delivered to EIPS. Contents of the package are described below.

4.1.5.1 Introductory Letter

The purpose of the *Introductory Letter* (Appendix 12) was to introduce the study to school principals and to seek their consent. The letter provided rationale for the study and included an outline of the investigative protocol. It also discussed dissemination of study results.

4.1.5.2 Information Letter

The *Information Letter* (Appendix 13) was intended to inform teachers, students and parents about the upcoming study. To ensure comprehensiveness, the letter was prepared at a Grade 9 reading level according to the Flesch-Kincaid Grade Level scale in *Microsoft Word® Version 7.0*. The letter included background information about IAQ parameters, what would be required of the participating schools, and who to contact for additional information about the study.

4.1.5.3 Response/Consent Form

The *Response/Consent Form* (Appendix 14) outlined the requirements of a participating school and requested permission from the principal. In addition, information was sought in order to prepare a sampling schedule.

4.1.5.4 Conduct Protocol

The *Conduct Protocol* (Appendix 15) was also included in the initial package to principals. This document described how investigators would conduct themselves during the study and was intended to introduce field procedures.

4.1.5.5 School Maintenance History Survey and *Screening Survey*

For each school that chose to participate, facilities personnel from the respective school boards were asked to complete a *School Maintenance History Survey* and *Screening Survey* (Appendices 16 & 17). Information from these surveys was then used to select schools for subsets and to provide blueprints for random selection of classrooms.

Prior to final printing, each of the documents was reviewed by the investigators, the HREB, and the "Steering Committee", consisting of representatives from each school board, the CHA and the University of Alberta.

4.1.6 Scheduling

Participating schools were contacted in mid September and January. Investigators suggested a tentative sampling date, requested contact information and school hours, and provided each school with a list of classrooms to be sampled. A scheduling template is shown in Appendix 18. All schools were scheduled for morning visits in order to limit temporal variation of measurements. To facilitate morning sampling, investigators scheduled meetings with facilities personnel prior to the first class of the day.

Scheduling of all schools for each round was completed at least one week prior to sampling to ensure sufficient advanced notice. Sampling in round one extended from October 10 to November 14/2001.

In round two, rescheduling of 14 schools was required to accommodate strike action. To ensure that sampling was not extended into the spring season, investigators reworked the sampling schedule to enable early investigation of schools not involved in the strike. The remaining schools were immediately rebooked following the strike. Winter sampling extended from January 21 to March 21, 2002 with a break during the strike from February 7 to February 22.

4.2 Selection of Air-Sampling Methodology

While considering a research methodology, investigators had to reconcile 1) study objectives; 2) operational stipulations; and 3) methodology requirements. Research objectives stipulated collection and analysis of baseline IAQ data from schools. Operational stipulations included financial and human resource limitations as well as consideration of school operating hours and regulations. Furthermore, The Capital Health Authority selected and supplied all of the air-monitoring equipment used in the study. Finally, the methodology selected had to support measurement of several environmental parameters including indoor airborne mould levels, CO_2 and CO levels, ventilation rates, RH and temperature. The following is a discussion of the air-sampling instruments provided for the study.

4.2.1 Bioaerosol Monitor

Currently, there is no standardized method for the sampling of airborne moulds, and a wide range of samplers may be used. To select an appropriate sampler, Macher and Burge (2001) recommend considering the following:

- Properties of particles to be collected
- Sampling locations
- Sample duration
- Volume of air to collect

Properties of Particles

Air samplers are designed with a specific array of microorganisms in mind. Method of collection, coupled with the size of particle that can be collected will determine the makeup of the sample. Table 9 demonstrates the various methods available for sampling airborne moulds.

Table 9: Methods of Sampling for Airborne Microbes (Macher and Burge,2001)

Method	**Rate and Time**	**Cut-off Size of Particle (μm)**
Total count		
Gravity slide		Unknown
Burkard trap	10L/min; 7 days	Unknown
Rotating arm impactors	47L/min; 15-60 sec	Unknown
Filter methods	1-4 L/min; ca. 4h	Unknown
Viable count		
Open Petri dish		Unknown
Andersen 6-stage impactor	28.3 L/min; 1-30 min	0.65
Andersen 2-stage impactor	28.3 L/min; 1-30 min	0.65
Andersen 1-stage impactor (N6)	28.3 L/min; 1-30 min	0.65
Reuter Centrifugal impactor (RCS®)	Ca. 40 L/min; 30sec – 8min	3.8
Reuter Centrifugal Plus impactor (RCS Plus®)	Ca. 50 L/min; 30sec – 8min	Unknown
Slit samplers	10-30 L/min	0.7
Liquid impingers	12.5 L/min	0.3

According to Table 9, the three basic methods of particle collection are filtration, impaction, or impingement into a liquid (Macher and Burge, 2001). Each of these methods pulls a measured volume of air with the aid of an electric or battery-powered pump. The air is then directed through a chamber (or a series of chambers), guiding the propagules on a specific trajectory to a solid agar disc or adhesive medium (impactor samplers), a liquid buffer (impinger samplers), or a filter (filtration samplers). Agar impactors are most frequently used to obtain information on particles with culturable bacteria or moulds (Hansen, 1999).

A microorganism may or may not be collected by a sampler depending on its size. For example, Table 9 indicates that a Reuter Centrifugal impactor (RCS®) will collect particles down to 3.8 μm in size while the cut-off size of particle that the RCS Plus® (Biotest AG, Frankfurt, Germany) instrument can collect is unknown. Table 10 indicates the variation in spore size from a variety of moulds (Kowalski and Bahnfleth, 1998). Mould spores may range in size from 2 to 100 μm in diameter (Kowalski and Bahnfleth, 1998). Consequently, an RCS® will represent a majority of the spectrum, but may omit important species present that are smaller than 3.8 μm in diameter.

Table 10: Mean Diameters of Mould Propagules (Kowalski and Bahnfleth, 1998)

Mould	Mean Diameter (μm)
Alternaria	14.4
Aspergillus	3.5
Aureobasidium	5.0
Chaetomium	5.5
Cladosporium	9.0
Epicoccum	17.3
Fusarium	11.5
Mucor	7.5
Penicillium	3.3
Phoma	3.2
Rhizopus	8.0
Scopulariopsis	6.0
Stachybotrys	5.6

Sampling Locations

Location of a sampler should reflect sampling objectives. For the purpose of this study, baseline mould levels were collected in pre-assigned locations in each classroom. The purpose of pre-assigned locations was to minimize bias that random locations may introduce into the study. (Chatigny, 1989).

Selection of a sampling location will have an impact on the microflora collected. For example, it is recommended that the RCS Plus® be set up at least one meter from the wall and from a room occupant (Burge, 1988). This enables the sampler to collect an average quantity of particles suspended in the air. In addition, a sampler should be situated in as unobtrusive a way as possible, to allow room occupants to participate in regular activities.

Duration of Sample

Since concentration of most airborne biological contaminants will vary with time, recognition of temporal variance is necessary to correctly interpret results. As a general rule in environments where concentrations are expected to be low, longer sampling periods are recommended in order to provide a better picture of what moulds are present (AIHA, 1996). However, longer sampling periods may cause desiccation of the sample and overgrowth of colonies too numerous to count (AIHA, 1996). Consequently, current mould guidelines are based on grab sampling measurements (Rao and Burge, 1996).

Volume of Sample

Sample duration directly impacts volume collected. For example, for an RCS Plus®, a six-minute grab sample at 50 L/minute represents a volume of 300 L. At this volume of air, mould is visible upon culturing, but not difficult to quantify. The lowest detectable limit (LDL) of a 300 L sample is 3 CFU/m^3. While a level of detection of 1 CFU/m^3 could be achieved with a volume of 1000 L, such a large sample would likely reduce viability of collected organisms due to the apparent desiccating effects of high velocity air flow on media (AIHA, 1996).

4.2.1.1 Limitations of Bioaerosol Samplers

No standard method is available for sampling airborne microorganisms. Furthermore, in the absence of visible reservoirs, air sampling will rarely confirm airborne mould contamination resulting from indoor growth (Burge *et al.*, 1977). Consequently, the American Conference of Governmental Industrial Hygienists (ACGIH) committee on Bioaerosols does not recommend air sampling, particularly if no apparent sources of biocontaminants are identified in the original investigation (Etkin, 1994). In general, air sampling should only be done to confirm that specific reservoirs are producing airborne contamination (ACGIH, 1989).

ACGIH lists the limitations of air sampling as: 1) difficulty identifying and quantifying the organisms involved, 2) lack of standards of "acceptable" contaminant levels and 3) unreliability of collected data (Etkin, 1994).

4.2.1.1.1 Identification/Quantification of Organisms

All analytical methods are subject to various limitations. Culture and microscopy may not detect some biological agents and allow only limited identification of those that are detected. In addition, while many moulds will grow on general culture media, others are not culturable under any conditions, or grow poorly in the laboratory (Macher and Burge, 2001).

Gravitational recoveries depend on the aerodynamic size and density of individual particulates or aggregates and vary with velocity and relative turbulence of airflow. According to Stoke's Law, the largest and heaviest spores will settle out more quickly, with smaller spores being suspended for longer periods of time (Godish, 2001). Mould spores and fragments range from 1 µm to 100 µm in size (Macher and Burge, 2001). In extreme cases, small microbial particles may escape detection despite high levels of prevalence in moving air (Solomon, 1976).

In addition, mould spores may not be spherical in shape, affecting their movement through air. Furthermore, spores may be released as single structures or in strands of multiple attached spores, such as *Penicillium* and *Cladosporium* (Godish, 2001). In theory, multiple attached spores will settle out more rapidly. Table 11 indicates the settling velocities for particles of different aerodynamic diameters.

Both viable and non-viable mould particles are important and should be sampled (Maroni, 1995). Many airborne spores are not viable and are not microscopically distinctive, so they cannot be identified using currently available methods (Maroni, 1995). For instance, in the case of *Stachybotrys atra*, 8 out of 10 spores would not be viable (Miller, 1990).

Table 11: Settling Velocities for Particles of Different Aerodynamic Diameters (Godish, 2001)

Particle Diameter (µm)	Settling Rate (cm/s)
1	0.004
5	0.08
10	0.30
20	1.20

4.2.1.1.2 Standards

Few guidelines exist for mould levels. Current proposed guidelines (Appendix 1) are largely based on anecdotal evidence and measurements taken in surveys of complaint and control buildings (Etkin, 1994). Health Canada (1995) guidelines are based on four-minute samples with the RCS.

4.2.1.1.3 Unreliability

Data collected from an air sampler may be unreliable, particularly due to its dynamic nature interspatially, and temporally (Etkin, 1994). Research by Holt (1993) indicated that bioaerosol levels in buildings could vary interspatially or temporally by as much as 1000% (Etkin, 1994). Table 12 demonstrates the differing concentrations of airborne microorganisms collected with temporal and spatial variability.

Table 12: Concentration of Airborne Moulds Collected in Different Rooms of a Restaurant Throughout the Day (Flannigan, 1992)

Airborne Mould Concentration (CFU/m^3 air)			
Area	**Morning**	**Mid-Day**	**Early Evening**
Pantry	212	141	129
Dining Room	35	565	24

4.2.1.2 Theory of a Centrifugal Air Sampler

A centrifugal air sampler operates on the principal of impaction (Biotest, 1996). An air stream enters the rotor at the front of the instrument and is set into rotation by the movement of the fan. Microbes contained in the air are then separated and impacted onto the agar strip through centrifugal force. To prevent the occurrence of turbulence in the air inlet chamber, the air outlet passage is parallel with the instrument directed to the rear (Biotest, 1996).

4.2.1.3 Biotest RCS Plus®

Section 4.2.1 outlines the wide variety of instruments that can be used for mycological air sampling investigations. The RCS Plus® was selected for this investigation for its self-containment, portability and convenience of use (Chatigny, 1989).

The RCS Plus® is illustrated in Figure 11. The collecting part of the sampler consists of a centrifugal fan that rotates in a cylindrical housing. The agar medium is mounted on a plastic strip that can be inserted around the inner periphery of the rotor. The rotor attaches via magnetic coupling flange to the polycarbonate housing of the RCS Plus®. A stainless steel protection cap must be situated over the rotor in order for the instrument to function. Rechargeable batteries, along with timing and control systems are mounted in the rectangular unit. The speed of rotation of the fan is 6100 rpm with a sampling volume of approximately 50L/minute (Biotest, 1996).

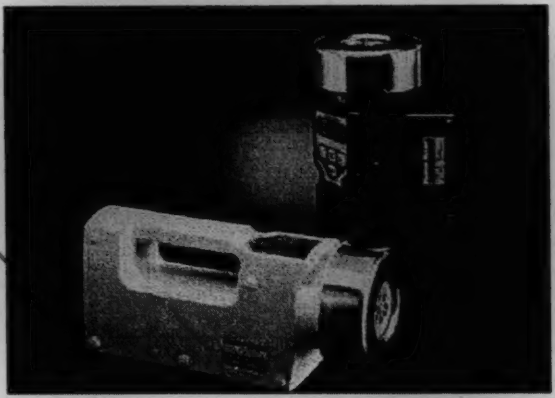


Figure 11: Diagram of the RCS Plus Sampler (Courtesy of Biotest Diagnostics Corporation, Denville, NJ)

4.2.1.3.1 Limitations of the RCS Plus®

While development of an all-purpose air sampler for flexible conditions is ongoing, current air sampling techniques cannot consistently account for the broad spectrum of microbes and dynamic conditions found both indoors and outdoors. Consequently, even the most careful selection of a sampler will not be without limitations.

Although sampling rate for the RCS® is listed as 40 L/minute, previous evaluations of the RCS® (an earlier model of the RCS Plus®) have determined that air taken into the sampler greatly exceeds the manufacturer's figure for the sampling rate. However, the effective sampling rate appears to fall rapidly for unit density particles less than 5 µm in diameter (Clark *et al.*, 1981).

From Table 13, particles with a diameter (EPD) between 4 and 34.6 μm were collected with reasonable efficiency, while particles <4 μm were very poorly collected. A further study of spore recovery of the RCS® found that particles from 5-18 μm were collected at an average efficiency of 80% (Laflamme and Miller, 1992). In general, studies of the RCS® under controlled conditions indicated that the bioaerosol collector is suitable for determining concentrations of mould spores in indoor for particles >5μm, and up to a concentration of 3000 CFU/m^3 (Laflamme and Miller, 1992).

Table 13: Effective Sampling Rate of Various Particle Diameters (Clark *et al.*, 1981)

Particle diameter (μm)	*EPD (μm)	Effective Sampling Rate (L/min)
0.7	0.7	1.2
1.0	1.5	11
2.3	4.0	49
4.9	8.5	137
10.0	17.3	166
20.0	34.6	162

*EPD: equivalent particle diameter: diameter of a sphere of unit density (1g/cc) having the same settling rate as the particle, assuming a single spore and the density of the potassium iodide to be 3g/cc.

In field and laboratory tests, the RCS Plus® has been found to be equivalent to the SAS Super 90 (Bioscience International, Rockville, MD), but less efficient than the Andersen 2-Stage impactor (Graesby-Anderson, Atlanta, GA) (Burge, 1995).

4.2.2 Selection of Growth Media

Collection of bioaerosols is typically done on agar-based media and coated tapes or glass slides. Surface properties of agar may affect which particles are collected. For example, biological particles striking moist agar will generally stick, while other particles may rebound from the surface of the agar.

Following collection of samples, growth of mould depends on the agar used. Growth media for air sampling fall into two physiological categories: high water activity (general mould growth media such as malt extract agar or colony diameter restricting media such as rose bengal) and low water activity (used for detecting moulds grown on dry material). In addition, because the nutritive requirements for moulds vary widely, no single medium will enable the entire range of airborne moulds to be isolated (Maroni, 1995). Consequently, cultural recoveries are impacted by the selectivity of the media used. For example, nutrient-rich agar, such as Sabouraud agar is not suitable in that it favours vegetative growth, leading to overgrowth and making counting difficult (Maroni, 1995; AIHA, 1996). Malt Extract Agar (MEA) permits selective growth if dextrose and peptone are omitted (Maroni, 1995). Rose Bengal (RB) agar and its dichloran-supplemented variant are thought to be appropriate media for several reasons: they are restrictive of overgrowth, are relatively robust in shipping and allow a high level of *in situ* identification. Furthermore, RB is a commonly used antibacterial agent in mould studies (Burge *et al.*, 1977).

RBS (Rose Bengal-streptomycin) agar contains as its nutrients: glucose (10gm), peptone (2gm), KH_2PO_4 (0.5gm), and $MgSO_4 \cdot 7H_20$ (0.5gm) (Nevalainen *et al.*, 1995). It contains RB (50mg) as its inhibitor. RB-containing media has been shown to permit the isolation of various mould species without overgrowth of *Mucor* and similar moulds (Verhoeff *et al.*, 1992). Furthermore, some xerophilic moulds may also be isolated using RB agar.

4.2.2.1 Limitations of Rose Bengal Agar

All existing mould sampling media have recognized shortcomings, eliminating the ideal of using a perfected, standardized growth medium to evaluate potential aerosol mould problems. Studies have emphasized the risk of sporadic total suppression of mould growth that RB may impose. In addition, it may induce more subtle partial inhibition even with careful handling (Burge *et al.*, 1977). In one study by Nevalainen *et al.* (1995), approximately one-third of RB-containing plates were completely devoid of mould growth.

Furthermore, exposure to full sunlight is known to cause photoactivation of RB and subsequent toxicity to some mould species (Nevalainen *et al.*, 1995). To prevent this, preactivation of RB before incorporation into medium is possible.

4.2.3 Theory of the Q-Trak®

The Q-Trak® (Texas Scientific Instruments, Shoreview, MN) with CO Model

8551 monitor was used to measure CO_2, CO, temperature and RH (TSI, 2002b).

The Q-Trak® measures CO_2 by relying on its molecular absorption properties (TSI, 2002b). CO_2 molecules are known to absorb light at a specific wavelength of 4.26 μm. As gas molecules diffuse into the sensing chamber, infrared (IR) light is directed through the sensing chamber towards the detector. The detector filters out all light except wavelengths of 4.26 μm. Since other gas molecules do not absorb light at this wavelength, only the CO_2 molecules will affect the amount of light hitting the detector (TSI, 2002). The intensity of 4.26 μm light reaching the detector is inversely proportional to the concentration of CO_2 in the chamber. Therefore, in the absence of CO_2, the sensor will perceive full light intensity. By contrast, as concentration of CO_2 in the chamber increases, more of the 4.26 μm light will be absorbed, and the intensity of light striking the detector will decrease (TSI, 2002b).

Intensity of light striking the detector can be described by de Beer's Law:

$$I = I_0 e^{kP} \qquad \textbf{Equation 1}$$

Where I = intensity of light striking the detector

I_0 = measured signal with 0 ppm CO_2

k = a system dependent constant

P = concentration of CO_2

4.2.4 Theory of a Thermal Anemometer

Any instrument used to measure velocity can be referred to as an anemometer. A thermal anemometer operates on the principle that resistance of a heated wire will change with temperature variations. The temperature of a heated wire element will change according to the velocity of the air moving over it (Lippmann, 2001; McDermott, 2001).

There are two sensors within a thermal anemometer: an air velocity sensor and a temperature compensation sensor. The air velocity sensor is heated by means of control electronics. The temperature compensation sensor senses the ambient air temperature and forces the velocity sensor to stay at an elevated temperature relative to the surrounding air (TSI, 2002a).

The air velocity and temperature compensation sensors comprise opposite legs of a Wheatstone bridge (Figure 12). The circuit forces the voltage at points A and B to be equal by means of an operational amplifier. When the velocity sensor is cooled by adjacent air flow, resistance decreases. To maintain equilibrium at points A and B, the operational amplifier delivers more power to the top of the bridge. Thus, the power going into the top of the bridge is proportional to the velocity of the air flowing past the sensor (TSI, 2002a).

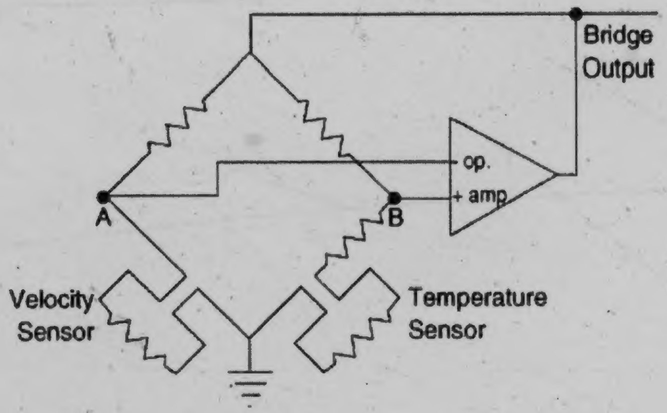


Figure 12: Wheatstone Bridge Diagram (Courtesy of TSI, 2002a)

4.2.4.1 Velocicalc® Air Velocity Meter

The Velocicalc® measures velocity of air using a hot wire sensor in a permanently attached probe. The instrument may measure a wide range of velocities, from 0 to 50 m/s. To access ducts located high on walls, the instrument includes a 101.6 cm telescoping prove (TSI, 2002a).

4.2.4.2 Alnor Standard Balometer®

The Alnor Standard Balometer® directly reads average airflow rate, either intake or outtake, from diffusers. This instrument allows reading of airflow rate by reading average velocity as air moves through a cross-section of known dimension. The Balometer® will measure airflow rates with an accuracy of +/-3% of full scale at both supply and return vents. The manifold is then connected to an Alnor Velometer®, capable of reading flow rates up to 2000 CFM. The Velometer® is a flow meter that receives air through its sensing ports. A force against the vane causes deflection of the needle that yields an indicated reading. A LoFlow® adapter may be used to accurately measure flow rate from low volume diffusers. This screen blocks 50% of the standard opening, increasing velocity by two times, and enabling an accurate measurement range between 50 to 250 CFM (Alnor, 2002). A schematic of the Standard Balometer® is provided in Figure 13.

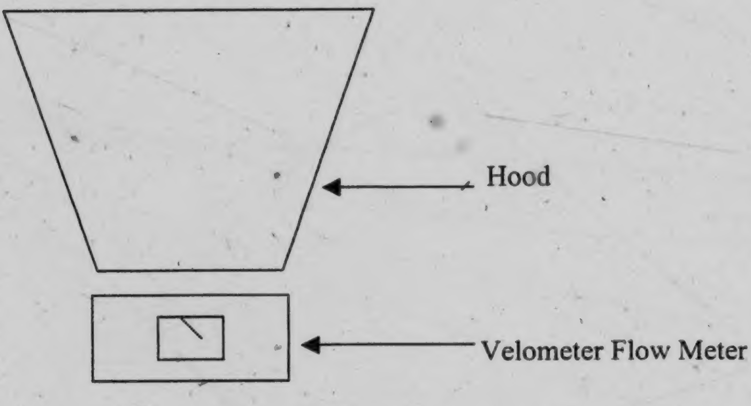


Figure 13: Schematic of Alnor Standard Balometer®

4.2.4.3 Limitations

Airflow instruments may be sensitive to environmental conditions such as temperature, humidity, atmospheric pressure and turbulence. For example, for optimal accuracy of the Alnor Standard Balometer® temperature should be in the range of 20-30°C. In addition, moist air may interfere with accuracy of thermo-anemometer readings if the moisture disrupts the change of resistance in the heated element (McDermott, 2001).

4.3 Field Procedure

The sampling protocol used in schools is listed in detail in Appendix 9. Each visit to a classroom lasted approximately 20 minutes. During this time period, the instruments were set up as summarized below.

The RCS Plus® was affixed to a tripod approximately 1 m from the floor, breathing height for students, and placed as close to the center of the classroom as possible. The RCS Plus® required a 5-minute sampling period, after which agar strips were put back into plastic containers, sealed with clear, adhesive tape, and placed in a cooler at approximately 5°C. Subsequent delivery to the National Mycology Laboratory (Edmonton, Alberta) occurred after all samples had been collected for the day.

The Q-Trak® was set up for a 15-minute sample period at the front of the classroom, approximately 1 meter from the floor. Consideration was taken to ensure that the instrument was at least 2 meters away from the breathing zone of any occupant, to prevent biased results.

The Velocicalc® was used to measure air velocity from each diffuser and into each return vent in the room. Equipment requirements, indoor sampling procedures and outdoor sampling procedures are detailed in Appendix 9. The Alnor Standard Balometer® was used along with the Velocicalc® instrument in selected classrooms. A subset of measurements was taken according to the *Sampling Protocol* in Appendix 9.

Data log entries were made for each instrument. In addition, a *Room Survey* (Appendix 20) was completed for each classroom, detailing room dimensions, number of occupants, and potential sources of IAQ concerns. Concurrent with indoor climate measurements, a self-report *Perception Survey* (Appendix 21) was distributed to teachers of randomly selected classrooms from those to be sampled. The questionnaire assessed the teacher's perceptions of six indoor air conditions at that time (hot, cold, stuffy, musty, humid or dry). Questions on environmental conditions were answered on a five-point Likert scale: strongly disagree, disagree, neutral, agree, and strongly agree (Salant and Dillman, 1994). Instructing participants to evaluate their perception of "today's" environmental conditions enabled investigators to compare results with measured indoor air parameters. Investigators also recorded the gender of the respondent in order to evaluate possible differences in response based on this variable.

In addition to the classroom air sampling, the room's air handling was investigated and results recorded in the *HVAC Survey* (Appendix 22).

Air sampling procedures for each round were as similar as possible. During the winter, however, measurements at outdoor air intakes were omitted due to the possibility of instrument malfunction below certain temperatures.

4.4 Laboratory Procedure

Once agar strips were received at the laboratory, they were incubated for 7-10 days at 25°C. Colony-forming units were then enumerated and mounted on a slide for identification. Moulds were identified according to color, texture, topography and rate of growth (Sand, 2001). Extent of identification (to the species or genus level) was determined by ease of identification and cost. For example, speciation of moulds such as *Aspergillus* was considered relevant and did not significantly add to the cost of identification.

4.5 Quality Control / Quality Assurance

Quality control and assurance refers to the process by which the quality of the data is ensured, beginning with the project design and concluding with the validation of the database. This includes the development of standard operating procedures, inclusion of measurements for estimation of accuracy and precision, documentation of field and analytical activities and data validation.

Prior to sampling, investigators completed a comprehensive sampling protocol that included the creation of standard operating procedures for each of the air quality instruments (Appendix 23). Standard operating procedures must also stand up to performance checks to ensure that measurement errors would be identified, were they to occur. To minimize this type of error, investigators included field and instrument blanks for each instrument in the procedures. A field blank identifies background levels of sample outside of the collection process. Obtaining a field blank for the RCS Plus® involved handling an agar strip identically to a sample strip, with the exception of actual sample collection. Field blanks were collected every week during the two sampling rounds, on the first day of each sampling week. To minimize bias in the laboratory, agar strips were submitted to the laboratory with coded labelling so that mycologists could not distinguish samples by their locations.

Contamination can occur during bioaerosol sampling, and should be minimized where possible. Opportunities for contamination include: 1) obstruction of sampling inlets; 2) lack of cleaning between uses; and 3) improper storage of samples. To minimize contamination, investigators incorporated a number of steps into the sampling protocol including sanitization of the RCS Plus® between uses and cold storage of biological samples (Appendix 9). To determine if the procedure itself contributed to background levels of airborne mould contaminants, investigators collected agar samples from a sterile environment. The "clean room" chamber used for this procedure was located at Toxcon Laboratories in Edmonton. Using the assumption that the chamber was free of bioaerosols, investigators obtained a series of samples under a variety of temperature and humidity conditions.

Consideration of accuracy and precision during an experiment enables minimization of systematic and random errors, respectively. The degree of correctness with which a measurement system yields a true value is termed accuracy (Watson *et al.*, 2001). To maximize accuracy, investigators manually calibrated both the RCS Plus® and the Q-Trak® prior to each round of sampling. The Velocicalc® instrument was factory calibrated prior to usage.

A definition of precision might be the expected variation of repeated measurements of the same parameter collected during the same measurement period (Watson *et al.*, 2001). Replicates of RCS Plus® measurements were done to evaluate precision of the mould sampling methodology. A replicate was done on the first day of every week during the two sampling rounds. Precision of the Q-Trak® sampling methodology was evaluated by comparing replicates of measurements in a classroom. Replicate measurements were performed in eight randomly selected schools. The procedure for performing replicates is detailed in the *Sampling Protocol* (Appendix 9).

Validity refers to something achieving what it is supposed to do rather than reflecting some other phenomenon. Sample/data validation involves several steps (Watson *et al.*, 2001):

- Examination of logbooks and chain-of-custody form for discrepancies
- Evaluation of data prior to submission to database.
- Identification of outliers within data sets and reinvestigation of values found to be contradictory to other values.

Following a day of sampling, investigators downloaded material from instruments onto the computer and evaluated the data sets for discrepancies. Inconsistencies in data were identified and either corrected or highlighted for discussion purposes.

4.6 Questionnaires

A questionnaire provides a tool for eliciting information that can be tabulated and analyzed. Questionnaires may distinguish between four types of information: 1) knowledge; 2) beliefs; 3) behaviour; and 4) attributes (Taylor-Powell, 1998). This study required questionnaires to evaluate attributes of schools, and general opinions about quality of indoor air.

4.6.1 Limitations

Research indicates that numerous factors may confound a response to a questionnaire, minimizing its effectiveness. Among these confounders are the construction of the questionnaire, the subjectivity that accompanies self-response, and the responsibility placed on the respondent (Taylor-Powell, 1998).

The form and wording of a research instrument will have an impact on the type and quality of information obtained. To facilitate the broad spectrum of information being sought, a combination of open and closed-ended questions were used for various questionnaires. Respondents to the *School Maintenance History Survey* provided in-depth information about school facilities, recent repairs and renovations. Closed-ended questions in the form of "ready made" categories on the *Pre-Screening Survey*, and *Perception Survey* helped to ensure that the information needed by the investigators was obtained. Most of the closed-ended questions were formatted as yes/no or multi-response options. However, the Likert attitudinal scale was used for the *Perception Survey* to adequately reflect subtleties in perception. This commonly involves a categorical scale intended to capture a wide spectrum of opinions (Taylor-Powell, 1998). Unfortunately, Likert scales are shown to be particularly prone to specific biases (Kumar *et al.*, 1999). End-aversion bias refers to the reluctance of some respondents to use extreme categories of a scale. This may reduce the range of possible responses. To address this issue, diluted categories were created, such as "strongly agree" and "strongly disagree" to avoid absolute-sounding terminology. A positive skew bias demonstrates heavily weighted responses towards the "favourable" end. While this bias is frequently seen when respondents are asked to evaluate coworkers, it was not expected to impact teacher's perceptions of environmental parameters, particularly since the results were anonymous.

Response to a questionnaire may be limited if the form is applied to a wide population, regardless of literacy, age or mental cognition (Kumar *et al.*, 1999). However, in this study, distribution of questionnaires was limited to school board facilities personnel, as well as principals and teachers of schools in the Edmonton area, ensuring respondents with a high level of comprehension. For the *Pre-Screening Survey, School Maintenance History* and *Screening Surveys*, response rate was not problematic since individual members of school boards completed all of them. However, for the *Perception Survey*, individual teachers were given several hours to complete the brief survey, in order to facilitate its completion. To avoid self-selecting bias, whereby a certain proportion of the sample chooses not to respond, investigators returned to classrooms to personally collect finished questionnaires (Kumar *et al.*, 1999).

Responses to questionnaires may be biased if respondents do not understand some questions, and do not have the opportunity to clarify their meanings (Kumar *et al.*, 1999). To avoid this bias, investigators issued questionnaires to teachers at the beginning of the classrooms visits, giving teachers up to 45 minutes to pose questions.

To further elucidate question wording, investigators included a glossary of terms directly below the body of questions.

4.6.2 Validation

To ensure the accuracy and quality of results obtained from a questionnaire, investigators should seek to establish its validity. Pre-testing is one method of validating a questionnaire. According to Salant and Dillman (1994), pretests should provide answers to the following questions:

- Does the question measure what it is supposed to measure?
- Do respondents understand the wording?
- Do all respondents interpret the questions the same?
- Does the questionnaire motivate people to respond?
- Does any aspect of the questionnaire suggest bias of the researcher?

A pretest of a questionnaire is a multi-step process, generally consisting of the following (Taylor-Powell, 1998):

- Critical review by colleagues.
- Pretest of questionnaire on people similar to population being tested.
- Simulation of data collection procedure.
- Collection of feedback regarding form and content of questionnaire.
- Ensuring that questionnaire yields data that is useful and can be analyzed.
- Evaluation and any necessary revisions of each question.

Pre-tests were conducted to varying extents on each of the surveys used throughout the investigation. The *Pre-Screening Survey*, *School Maintenance History Survey*, *Room Survey* and *HVAC Survey* were critically reviewed by the Steering Committee, which included representatives from the Capital Health Authority, EPS, EIPS, EICS, and the University of Alberta. In addition, investigators polled school facilities personnel for suggestions on what to include on the *HVAC*, *School*

Maintenance History and *Screening Surveys* and reviewed other air-handling unit surveys for appropriate content. Following this initial process, pretests of the *HVAC Survey* and *Room Survey* were completed at several schools while summer session was underway. Subsequent revisions to the form and content of the surveys were made to ensure ease of data compilation and analysis. To facilitate evaluation of data from the *Perception Survey*, a statistician at the University of Alberta was consulted. A Likert scale was used to permit accurate collection of attitudinal data and to enable comparison of ordinal results with interval measurements of parameters.

4.7 Data Analysis

Spearman's rank correlation (McBean and Rovers, 1998) was used to model the relationships between indoor and outdoor airborne mould levels and a combination of RH, temperature, occupancy level and ACH.

A paired sample t-test (Schefler, 1979) was used to analyze the effect of gender, by comparing the mean differences in perception of IAQ between male and female subjects. Ordinal logistic regression (Minitab, 2002) was then used to determine relationships between ordinal perception data and interval data of parameter measurements.

5.0 RESULTS and DISCUSSION

5.1 Response Rate

To ensure response from schools invited to participate, investigators conducted follow-up phone calls approximately one week after information packages were delivered to schools. Of the 43 schools that investigators originally approached to participate in the study, 40 agreed, equivalent to a response rate of 93%. The response rate was 91% from EPS and 100% from both EIPS and EICS. The exceptional response rate was likely due to the benefits inherent to the study and the minimal intrusiveness of the sampling protocol.

Studies that implement surveys or questionnaires are generally subject to diminished response rate, defined as the number of respondents who complete a questionnaire compared to the number assigned (Word, 1997). However, most of the questionnaires used for this study were either distributed to a small number of respondents, or completed by the investigators. Facilities personnel were contracted out to complete *Pre-Screening Surveys*, *School Maintenance History Surveys* and *Screening Surveys*. Likewise, investigators completed *Room Surveys* for each classroom sampled and *HVAC Surveys* for each school surveyed. Investigators ensured maximum response rate for the *Perception Surveys* by personally collecting them from participating teachers. Of the 53 *Perception Surveys* distributed, 52 were returned, giving a return rate of 98%.

5.2 Mould Results

In Canadian homes, average indoor RH range from 35-50% (Health Canada, 1995). An investigation of a Calgary-area school in the winter of 1996 demonstrated average indoor RH of less than 10% (Lee, 1996). While some moulds may survive and propagate under these conditions, low humidity is generally not ideal for indoor mould propagation. As expected, low levels of airborne mould particulates were collected from EPS, EIPS and EICS schools. In 32% of indoor air samples, the level of mould particulates was below the RCS Plus® detection limit (3 CFU/m^3 for a 300 L collection), defined as the lower limit at which measurements can be differentiated as quantitatively meaningful (McBean and Rovers, 1998). Only 15 out of 305 indoor samples had total aerosol mould counts equal to or above 150 CFU/m^3, the upper acceptable limit suggested by most agencies. The maximum number of airborne mould particulates collected was 650 CFU/m^3. Figure 14 indicates the distribution of total airborne mould levels collected over the course of the study.

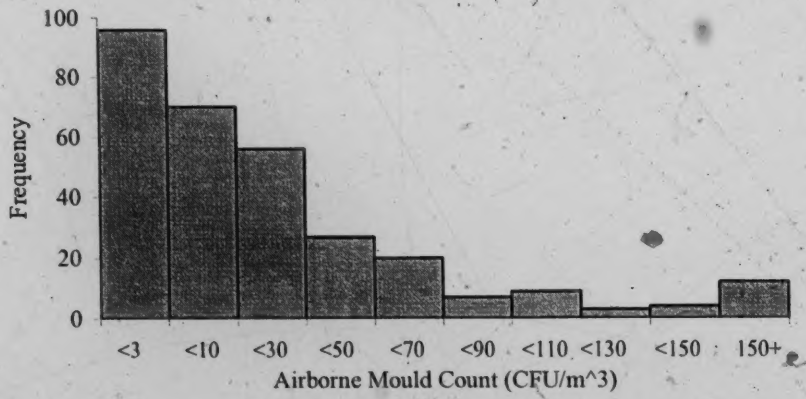


Figure 14: Distribution of Total Indoor Airborne Mould Data From Both Sampling Rounds

Airborne mould levels were expected to vary seasonally, with higher levels expected in the fall, and lower amounts anticipated in the winter sampling round. Figures 15 and 16 indicate the distribution of airborne mould levels over the fall and winter sampling rounds, respectively.

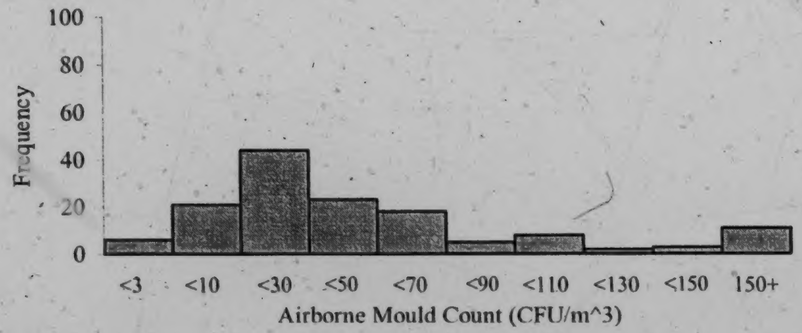


Figure 15: Distribution of Indoor Airborne Mould Data From the Fall Sampling Round

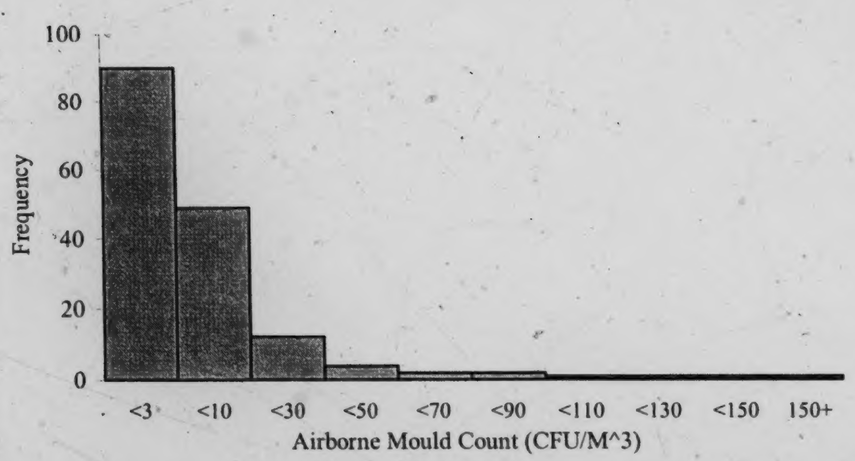


Figure 16: Distribution of Indoor Airborne Mould Data From the Winter Sampling Round

Figures 15 and 16 indicate visible differences between indoor airborne mould quantities over the fall and winter seasons. To account for this obvious variation, subsequent data analysis examined relationships observed overall and from a seasonal perspective.

As anticipated, the median count of total indoor airborne mould was higher during the fall sampling round (30 CFU/m^3) than the winter sampling round (below the detection limit). However, a significant quantity of readings was below the detection limit regardless of season.

Detection of airborne mould propagules is a sensitive process, dependent on many variables. While a higher volume of air might have permitted better quantification of mould species present, a low sampling time is recommended for the RCS Plus® so that culture media is not overloaded with mould growth (AIHA, 1996). In addition, higher sampling rates are thought to risk desiccation of sampling media, and prevent growth of mould (AIHA, 1996). Furthermore, the concentration of airborne mould particulates may vary temporally and also fluctuate according to spontaneous "fungal bursts" (Etkin, 1994). Quantification of airborne mould matter, along with standardization of a mould collection method remains an ongoing scientific challenge.

Twenty-four different moulds were cultured from aerosol samples, as listed in Appendix 24. Within the broad spectrum of mould collected, four major types were identified: *Cladosporium*, *Penicillium*, *Alternaria*, and Non-sporulating mould. These moulds exhibited detectable bioaerosol counts ($\geq$3CFU/m^3) 21% to 37% of the time. The remaining 20 moulds were detected less than 20% of the time. *Cladosporium* and *Alternaria* constitute major phylloplane mould, while *Penicillium* is a soil-borne organism. Non-sporulating mould are sterile mycelia that grow readily on malt extract agar, but do not sporulate (Barlett *et al.*, 1997).

5.2.1 Distribution/Censored Data

Using air-sampling instruments, investigators collected several types of data. Discrete, or discontinuous data is obtained by counting items. By contrast, continuous data involves measurements in more precise increments and an infinite number of possible measurements (Schefler, 1979). While measurements of CO_2, CO, RH, temperature and ventilation provided continuous data, mould results were discrete.

In general, environmental data such as stream quality information, wastewater treatment plant influent and air quality data are not normally distributed (Berthouex and Brown, 1994). Measurements of the concentration of airborne materials will often vary over time and follow skewed distributions. Outdoor concentrations of biological agents will vary according to the time of day, wind direction and RH. In the same way, indoor air concentrations may be affected by outdoor air ventilation rate, number of occupants or occupant activity (Macher and Burge, 2001) Consequently, it is common for distributions of air sampling data to be more flat-topped or sharp-topped than a normal distribution, or to be asymmetrical (Colquhoun, 1971).

Environmental quality data sets are frequently skewed to the left because concentration data are constrained on the low side (since concentrations cannot be negative) but not on the upper side (McBean and Rovers, 1998). In this investigation, the four major mould types that were studied exhibited between 63-79% non-detectable data, resulting in an asymmetrical distribution of data, skewed to the left.

Table 14 indicates the percentage of the indoor air samples of mould that fell below the detection limit.

Table 14: Percentage of Samples of Four Major Moulds That Fell Below the Detection Limit

Mould	Percentage Below LDL* (%)
Alternaria	79
Cladosporium	67
Non-sporulating	63
Penicillium	77

*LDL Lower Detection Limit

There have been numerous investigations of methods for estimating parameters for censored data (below the detection limit) drawn from assumed specified parent distributions such as the normal or lognormal (McBean and Rovers, 1998). In situations with censored data, zero values may often be replaced with a small constant, or by using half of the LDL (Burge, 1990). Burge further recommends repeating the sample, and adjusting the sample volume to obtain data within a reasonable range. Unfortunately, simple substitution tends to perform poorly in statistical tests when the nondetect percentage is substantial (McBean and Rovers, 1998). For example, in this study, using replacement of censored values to correct the skewed pattern was not recommended due to the high percentage of censored data.

The Maximum Likelihood Estimate (MLE) is one technique that substitutes values for censored data based on what is known about the distribution of the data reported above the detection limit and the percentage of data below the detection limit. The MLE is a favoured method to compute the median and other percentiles of a data set because it is less biased compared to simpler techniques that substitute zero, one-half, or the detection limit value for censored data (Helsel and Hirsch, 1992). The MLE works best with sample sizes greater than 25 (Helsel and Hirsch, 1992). However, as the extent of censoring reaches 20-50%, parameter estimates obtained using the MLE method suffer in terms of increased bias and variability (Berthouex and Brown, 1994).

Data censoring is considered severe at the level of 50 percent or more (Helsel and Hirsch, 1992). At censoring levels greater than 50 percent, the median concentration, for example, may have to be estimated because it is not a detected value. As expected, the median of each set of airborne mould particulate data, with censoring levels between 63% and 79%, was below the detection limit. Because of the high levels of non-detectable data in this study, Aitchison's Method was selected to calculate the geometric mean of the mould data. This approach requires that at least ten percent of the samples are detectable and assumes that nondetect samples are free of contamination, so that all nondetects may be regarded as zero concentrations (McBean and Rovers, 1998). In addition, it requires that detected samples follow an underlying normal or lognormal distribution (McBean and Rovers, 1998). The premise of the technique is based on the censored probability model whereby a new or adjusted mean and standard deviation is estimated (McBean and Rovers, 1998). The sample mean ($\bar{x}_d$) from the data above the detection limit is initially computed using the equation below:

$$\bar{x}_d = \frac{1}{m}\sum_{i=1}^{m} x_i$$ **Equation 2**

Where:
m = total number of samples

The sample variance (S_d^2) is then computed using

$$S_d^{\,2} = \sum_{i=1}^{m} \frac{(x_i - \bar{x})^2}{(m-1)}$$ **Equation 3**

Where:
d = number of nondetects
n = total number of samples (detects and nondetects)
The adjusted overall mean $\hat{x}$ is

$$\hat{x} = (1 - d/n)\bar{x}_d$$ **Equation 4**

And the adjusted overall standard deviation $\hat{S}$ becomes

$$\hat{S} = [(\frac{n-(d+1)}{n-1})(S_d)^2 + \frac{d(n-d)(\bar{x}_d)^2}{n(n-1)}]^{0.5} \qquad \textbf{Equation 5}$$

Adjusted means and standard deviations calculated from the mould data are indicated in Table 15. Values used in the calculations are given in Appendix 26.

Table 15: Adjusted Means and Standard Deviations of Indoor Airborne Mould Data Calculated Using Aitchison's Method.

Mould	Round	Adjusted Mean	Adjusted Standard Deviation
Alternaria	Both	2.84[a] (3[b])	8.96 (9)
	Fall	5.82 (6)	13.8 (14)
	Winter	0.27 (0)	1.55 (2)
Cladosporium	Both	6.34 (6)	16.4 (16)
	Fall	13.5 (14)	26.0 (26)
	Winter	0.09 (0)	0.527 (1)
Non-Sporulating	Both	3.87 (4)	7.66 (8)
	Fall	7.03 (7)	9.10 (9)
	Winter	1.11 (1)	4.92 (5)
Penicillium	Both	9.30 (9)	44.7 (45)
	Fall	12.5 (12)	41.9 (42)
	Winter	3.08 (3)	17.7 (18)

a Computed value using Aitchison's Method (after McBean and Rovers, 1998).
b Rounded value to reflect the fact that fractions of mould do not exist.

A higher overall mean for both *Penicillium* and *Cladosporium* is suggestive of higher incidents of occurrence. In the case of *Pencillium,* this outcome more accurately reflects high concentrations of airborne mould particles that were observed infrequently. Use of Aitchison's Method enabled calculation of adjusted means that accounted for censored data and yielded numbers that were less than the LDL, such as the adjusted means calculated for *Alternaria, Cladosporium* and non-sporulating mould during the winter sampling round.

Seasonal variation in indoor aerosol mould counts is observed in Table 15. Adjusted means vary significantly between fall and winter for each mould type. Lower outdoor levels of mould in winter likely contribute to diminished indoor levels. Adjusted averages of both *Alternaria* and *Cladosporium* are 0 CFU/m^3 in the winter sampling round, possibly due to their phylloplane nature. Higher levels of *Alternaria* and *Cladosporium* recorded in the fall sampling round reflect the leaves and trees still present at the time.

5.3 Humidity Results

The average RH recorded over 15-minute sampling intervals in classrooms was 24.4% overall, 28.3% in the fall and 20.4% in the winter. A total of 201 data points obtained from measurements in 156 classrooms were continuous and normally distributed over a range from 13.3% to 37.2%, on the low end of NIOSH guidelines of between 20 to 60%. Raw data is available in Appendix 27. Figure 17 indicates normally distributed humidity data.

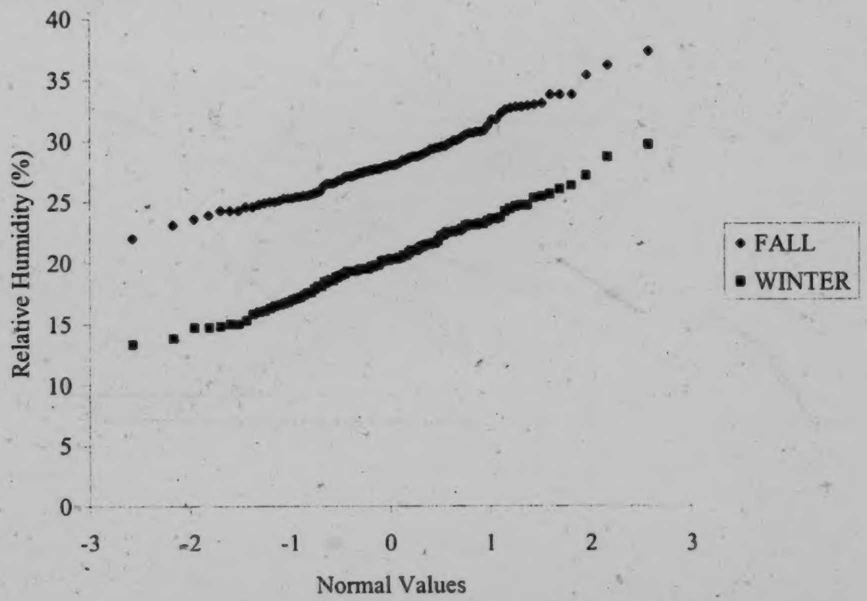


Figure 17: Normal Probability Plot of Indoor Relative Humidity Measurements Over Two Rounds of Sampling

Figure 17 suggests that indoor RH levels decreased by approximately 8% during the winter sampling round, possible due to decreased use of outdoor air for ventilation purposes in the winter months. In the winter, outdoor ventilation rates must be minimized in order to maintain an acceptable indoor temperature without maximizing energy consumption. Recirculation of indoor air may contribute to diminished RH levels.

5.4 Temperature Results

There were 201 15-minute temperature readings obtained from 156 classrooms. Temperature data is included in Appendix 27. Results indicate continuous, normally distributed data ranging from 16°C to 25°C, with a mean temperature of 21.6°C. This average temperature falls within the recommended range for indoor temperatures as specified by ASHRAE *Standard 55-1992*. The average indoor temperature was 22°C in the fall, and 21.3°C in the winter. Figure 18 demonstrate the normal probability plots of temperature values during fall and winter sampling rounds.

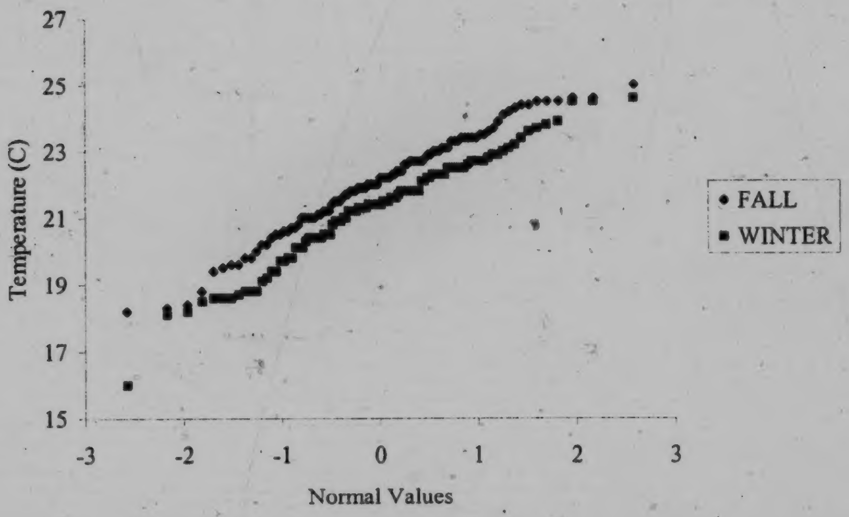


Figure 18: Normal Probability Plots of Indoor Temperature Measurements Over Two Rounds of Sampling

From Figure 18, winter temperatures appear to be approximately 1°C less than fall temperatures. Slightly colder temperatures in winter months may be due to "leakage", or infiltration of cold outdoor air into classrooms.

5.5 Ventilation Results

The Velocicalc® Plus operates with an accuracy of ±3%, but is typically used to conduct duct traverses (TSI Inc., 2002a). The Alnor Standard Balometer® also operates with an error of ±3%, but enables measurement of air flowrate at the diffuser level. While the Velocicalc® Plus was the predominant instrument used to collect ventilation data for this project, the Alnor instrument was made available to investigators for a period of two weeks. Flowrate data obtained using the Velocicalc® Plus instrument was then compared to data collected using the Alnor Standard Balometer®. Calculation of the best-fit model for corrected flowrate using the maximum least estimate method is given in Appendix 28. Regression of the data sets produced a coefficient of determination (r^2) of 0.554, suggesting a weak relationship between measurements obtained from each instrument. Equation 6, created using the maximum least estimate method, enables correction of data collected with the Velocicalc® Plus.

$$\text{Corrected Flowrate } [m^3/h] = 0.554(\text{Flowrate Velocicalc}^{\circledR}[m^3/h]) + 159$$ **Equation 6**

To minimize bias of ventilation measurements, only those flowrates obtained from classrooms with unit ventilators were used to calculate ACH. Ventilation data is available in Appendix 29. Typically, a unit ventilator was the only source of mechanical ventilation for these classrooms, enabling accurate depiction of supply and return rates. ACH data ranged from –2.4 to 6.9 with a mean ventilation rate of 2.6 ACH. While the maximum and average ACH values are much higher than those recommended for a school facility, important ventilation factors, such as natural ventilation rate, were not included in the computation. Ventilation loss through doors and windows would significantly reduce the ACH from the recorded value. Negative ACH values suggest that more air is leaving the classroom than is being added.

However, additional air entering the classroom from hallways through open doors was not recorded, and may have contributed to a momentary return flowrate that was greater than the supply flowrate. Furthermore, because the correlation coefficient used in equation 6 was relatively weak (0.554), calculated values for corrected flowrate may not be entirely accurate. Consequently, ACH values calculated from these flowrates may also reflect this inaccuracy.

ACH values may also be influenced by recorded room volumes. Investigators were able to measure classroom length and width but often had to estimate height. As a result, investigators may have over or under approximated actual room volume.

5.6 Correlation Results

To analyze data arising from this study, non-parametric (distribution-free) tests were necessary because assumptions required for parametric analysis could not be met. The fundamental characteristic of nonparametric procedures is that the ranks of the data are utilized instead of data values (Berthouex and Brown, 1994). Despite this, for data that do not fulfill the assumptions necessary for parametric analysis, the nonparametric methods are considered as powerful or more powerful than the equivalent parametric tests (Berthouex and Brown, 1994).

Spearman's rank correlation is a distribution-free analog of correlation analysis (McBean and Rovers, 1998). Like regression, it can be applied to compare two independent random variables, each at several levels (which may be discrete or continuous). Unlike regression, Spearman's rank correlation works on ranked (relative) data, rather than directly on the data itself. Like the r^2 value produced by regression, Spearman's coefficient (r_s) indicates agreement. A value of r_s near positive or negative one indicates good agreement; a value near zero, poor agreement (Berthouex and Brown, 1994). The Spearman's rank correlation coefficient may be calculated by equation 7.

$$r_s = 1 - \left(\frac{6\sum d^2}{n^3 - n}\right) \qquad \textbf{Equation 7}$$

Where:
n = the number of samples ranked
d = the rank difference.

5.6.1 Indoor and Outdoor Mould

The level of bioaerosols in an environment is dependent on the source of the contaminant. Indoor mould types and quantities frequently reflect outdoor mould make-up. Phylloplane, or leaf-surface moulds, such as *Cladosporium* and *Alternaria* are among the principal outdoor moulds and typically flourish in fall months (Tobin *et al.*, 1987). By contrast, during the winter season, tree moulds cannot survive. Correspondingly, higher indoor levels of *Cladosporium* and *Alternaria* were expected in the fall. Several studies have shown that *Penicillium* spp. in indoor air do not follow the outdoor seasonal periodicities and are generally regarded as indoor moulds (Wurtz *et al.*, 1999). A 1995 Canadian study found that *Penicillium* formed <4% of the outdoor spora but nearly 20% of indoor spora. *Penicillium* is frequently found at the sub-basement levels of offices and rooms, in libraries, auditorium, storage rooms and in ventilation systems (Wurtz *et al.*, 1999).

Data was analyzed using Spearman's rank correlation, using the null hypothesis that there was no difference between outdoor and indoor airborne mould levels. In general, a Spearman's rank correlation value (r_s) above 0.5 indicates a significant relationship between variables. Calculations of Spearman's rank correlation values are given in Appendix 30. Table 16 indicates the relationship between indoor and outdoor mould counts.

Table 16: Relationship Between Outdoor and Indoor Airborne Mould Levels

Mould	Spearman's Rank Correlation (r_s)		
	Overall	Fall	Winter
Alternaria	0.97	0.70	1.0
Cladosporium	0.94	0.50	0.92
Non-sporulating	0.90	0.45	0.96
Penicillium	0.75	0.44	0.90

Results suggest strong overall relationships between indoor and outdoor airborne mould levels. While these results correctly depict the effect of outdoor levels on indoor levels, it should be noted that the vast majority of mould levels during the winter sampling round were censored, diminishing the robustness and validity of the data set.

By contrast, a greater number of noncensored values were collected during the fall sampling round. Consequently, fall correlation values better reflect the relationship between indoor and outdoor mould levels. As expected, the strongest relationships exist between indoor and outdoor levels of *Alternaria* and *Cladosporium*, while *Pencillium* exhibits a weaker relationship between indoor and outdoor levels. This supports the belief that *Penicillium* reservoirs are typically found indoors. A weak association between outdoor and indoor level of airborne non-sporulating mould is also evident from Table 16. However, the relationship is ambiguous since "non-sporulating" describes a wide assemblage of sterile moulds. Future investigations should examine outdoor and indoor relationships between specific species of non-sporulating moulds.

5.6.2 Temperature and Mould

Literature indicates that temperature may influence mould growth depending on the type of mould. For example, certain moulds, such as *Cladosporium,* are able to grow at temperatures as low as –6°C, while thermophilic moulds will thrive at temperatures as high as 55-60°C (Godish, 2001). In general, however, most moulds are able to grow at temperatures between 10-35°C, a range encompassing the temperatures measured in classrooms (Godish, 2001). While previous studies suggest relationship between temperature and mould growth, its effect on the concentration of airborne mould propagules is not known.

Table 17 indicates the correlation coefficient values between indoor temperature and the concentration of airborne mould propagules. Little or no relationship is seen between indoor temperatures and measured mycoaerosol levels overall.

Table 17: Relationship Between Concentration of Airborne Mould and Temperature From Two Rounds of Sampling

Mould	Spearman's Rank Correlation (r_s)		
	Overall	Fall	Winter
Alternaria	-0.06	0.12	-0.67
Cladosporium	0.02	-0.02	-0.81
Non-sporulating	0.21	0.07	-0.26
Penicillium	0.19	0.22	-0.31

Results suggest that indoor airborne mould levels in the fall were not significantly influenced by temperatures between 16-25°C. Since the majority of mould grows at temperatures between 10-35°C, clearly delineated relationships between temperature and levels of specific airborne moulds were not anticipated. However, examination of results from a seasonal perspective indicates a persistent inverse relationship between temperature and mould during the winter sampling round. Evaluation of winter round mould data indicates that the vast majority of data fall below the detection limit (Table 14). Because of the lack of robust data in the winter mould results, comparisons between indoor airborne mould concentration and IAQ parameters should not be made. Further analysis of correlations will focus on overall and fall data sets only.

5.6.3 Humidity and Airborne Mould

Past studies suggest that as RH increases, mould particles are less likely to be released to the air. In addition, smaller spores (such as those of *Aspergillus* or *Pencillium*) tend to become airborne more readily than larger spores (*Cladosporium*) (Pasanen, 1991).

In this study, average humidities in the fall and winter sampling rounds were very low, 28.3% and 20.4% respectively. At such low humidities, higher spore release would be expected. Table 18 indicates the relationship between the concentration of indoor airborne mould propagules and RH levels. Results demonstrate weak correlation coefficients between RH and airborne mould levels overall or in the fall sampling round. However, since RH never rose above 37.2%, indoor conditions were consistently dry. Consequently, fluctuations in release of mould particulates may not have been as distinct as if a wider range of humidities were represented.

Table 18: Relationship Between Concentration of Airborne Mould and Relative Humidity from Two Rounds of Sampling

Mould	Spearman's Rank Correlation (r_s)	
	Overall	Fall
Alternaria	-0.01	0.2
Cladosporium	0.34	0.22
Non-sporulating	0.37	0.31
Penicillium	0.03	0.27

5.6.4 Ventilation and Mould

The association between ACH and contaminants depends on many parameters. Some studies indicate that ACH cannot be correlated with the levels of some pollutants, such as certain VOCs. In other instances, increased ACH is shown to increase contaminant levels, such as radon (Bearg, 1993).

Literature suggests that in an ideal plug-flow situation, with outdoor air devoid of contaminants, increased ACH rates would result in an exponential decrease in indoor contaminants. Theoretically, the more fresh air circulated through a room, the less contamination. However, in this study, outdoor air provided a reservoir of airborne mould for transportation indoors. Consequently, expectations were that, dependent on outdoor bioaerosol concentrations, increased ventilation rates would more quickly bring indoor and outdoor bioaerosol concentrations to an equilibrium. In this study, relationships between indoor bioaerosol levels and ACH levels varied according to season. In general, measurements of outdoor airborne mould levels were below the detection limit in the winter and above the detection limit in fall.

Table 19 indicates the relationship between the concentration of indoor airborne mould and air exchange rates from overall and fall sampling rounds. Correlation values are between –0.01 and 0.34, depending on season and type of mould.

A positive association between *Cladosporium* and ACH was expected from the fall sampling round. Current standards recognize that *Cladosporium* is a predominant outdoor mould in North America and is easily transported indoors via

Table 19: Relationship Between Indoor Airborne Mould Levels and Classroom Air Exchange Rates

Mould	Spearman's Rank Correlation (r_s)	
	Overall	Fall
Alternaria	-0.01	0.09
Cladosporium	0.32	0.20
Non-sporulating	0.27	0.34
Penicillium	0.10	0.23

ventilation. Consequently, higher rates of ACH would theoretically increase *Cladosporium* numbers indoors incrementally. As expected, a weak, positive association is evident between fall airborne *Cladosporium* levels and ACH. Similar weak, but positive associations exist between Non-sporulating and *Penicillium* airborne data and ACH levels. However, correlation values are below 0.5, the lower limit for significant relationships.

While relationships between levels of indoor airborne moulds and ACH during the fall are not shown to be significant, the relationship between *Penicillium* and ACH is stronger than that of both *Cladosporium* and *Alternaria*. A possible explanation for this strength of relationship is the size of mould particle. While *Cladosporium* and *Alternaria* spores are larger, with diameters of 9.0 µm and 14.4 µm respectively, a typical *Penicillium* spore is only 3.3 µm in diameter (Kowalski and Bahnfleth, 1998). Hence, according to Stoke's Law, *Penicillium* spores would be suspended for a longer time than spores with larger diameters (Macher and Burge, 2001).

The role of ACH in clearing airborne mould from an indoor environment might be better understood in a controlled environment. In this study, confounding factors such as the presence or absence of rugs or plants, and the use of natural ventilation may have significantly affected air samples. For example, *Cladosporium* is commonly associated with textiles, and might be present to an unusual degree in environments with carpeting or cushions. In addition, *Penicillium* is found in soils and would be a more significant indoor presence where potted plants were prevalent.

Effectiveness of a ventilation system in delivering outside air to an occupied zone may be affected by many variables including configuration of supply and return air circuits, working room volume, rates of air circulation, and presence of interior partitions (Offerman and Int-Hout, 1989). In this study, several ventilation variables were not accounted for. Since calculation of ACH is dependent on the working volume of the room, including partitions and hanging ceilings, values calculated using the dimensions of the room might have been inaccurate. In addition, a study by Chung and Hsu (2001) determined that ventilation efficiency might be dominantly influenced by location of diffuser rather than ACH, a variable not considered in the study. In this study, outside airflow rate was measured using air velocity scans across the face of the air supply and then subtracting the return rate. Other potentially significant sources of ventilation, such as duct leakage and infiltration were not detected with this technique.

5.6.5 Occupancy and Mould

Table 20 indicates the relationship between the concentration of airborne mould propagules and the occupancy level in classrooms from overall and fall samples.

Table 20: Relationship Between Indoor Airborne Mould Levels and Classroom Occupancy Level

Mould	Spearman's Rank Correlation Values (r_s)	
	Overall	Fall
Alternaria	-0.07	0.28
Cladosporium	0.09	-0.02
Non-sporulating	0.19	0.32
Penicillium	-0.06	0.16

Spearman's rank correlation values overall and during the fall sampling round are very low for all moulds studied, suggesting no significant relationship between airborne mould levels and the number of occupants in a room. While results seem to indicate no relationship between these occupancy levels and airborne mould levels, factors that may have impacted results include ventilation rates (natural and mechanical), movement and activities of room occupants, and whether students had just arrived in the class, or had been there for a longer period of time (Tobin *et al.*, 1987).

Ventilation rates, both natural and mechanical may have confounded results by either elevating or lowering airborne mould levels. Similarly, open windows permit influx of microbes from the outdoors, and open doors may have introduced mould from other parts of the school.

In general, a high level of room activity is thought to generate air turbulence, which may affect the suspension and sedimentation of mould particles, depending on the shape, size and weight of the particle (Tobin *et al.*, 1987). In addition, people may act as transportation for mould particulates from outdoor sources. Depending on the location of the school, students may bring in specific mould types. However, particulates may settle as students spend more time in a sedentary classroom environment. Since information gathered from each classroom did not include past activity of classroom participants, this factor could not be controlled for.

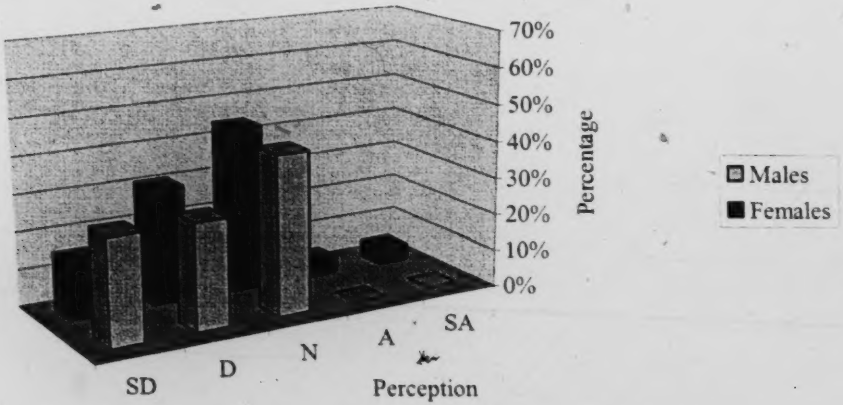
5.7 Perception Results

Perception Surveys were distributed during the winter sampling round only. Of 53 *Perception Surveys* distributed, 52 were returned. Of the respondents, 45 were female and 7 male. Raw data from the *Perception Survey* is given in Appendix 32.

5.7.1 Perception by Gender

Numerous factors may confound how individuals perceive environmental conditions. Previous studies have suggested that gender may strongly influence the results of a perception study. Brill *et al.* (1984) theorized that women are less satisfied with the temperature in buildings because they typically have a smaller body mass and may be more strongly affected by temperature changes. In addition, differences in complaint behaviour may be due to gender differences in clothing insulation or environmental exposure. While it has been demonstrated that women are more sensitive to deviations from preferred temperatures, studies have shown that both genders have similar temperature preferences (Fanger, 1982).

From the experimental data, a minority of respondents found classroom temperatures to be hot or cold. As indicated in Figure 19, only 8% of females agreed or strongly agreed that temperature was hot. None of the male respondents found classroom temperatures to be hot.



SD Strongly Disagree D Disagree N Neutral A Agree SA Strongly Agree

Figure 19: Comparison of Male and Female Teachers' Perceptions That It Was "Hot" in Classrooms

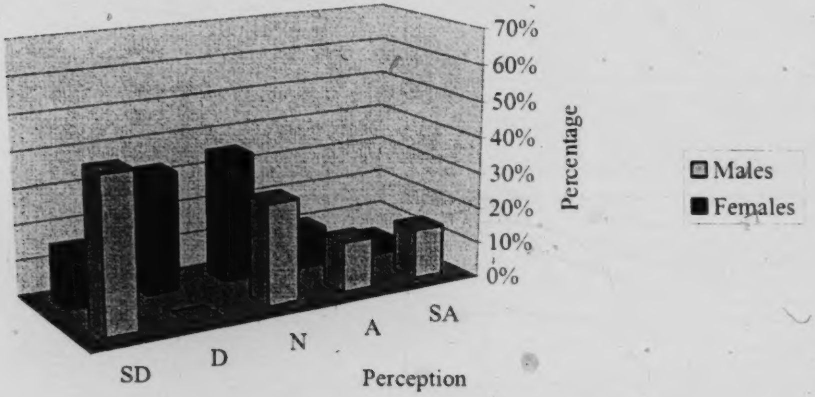


Figure 20: Comparison of Male and Female Teachers' Perceptions That It Was "Cold" in Classrooms

Figure 20 indicates that 15% of females found classroom temperatures to be cold, compared with 28% of men. A larger percentage of respondents disagreed that temperatures were hot or cold. Forty-three percent of men and 49% of women either disagreed or strongly disagreed that classroom temperatures were cold, while 58% of men and 47% of women disagreed or strongly disagreed that room temperatures were hot.

Perception of mustiness in the classroom, defined in the survey as "a stale or mouldy odour", was generally low. Figure 21 indicates the distribution of results.

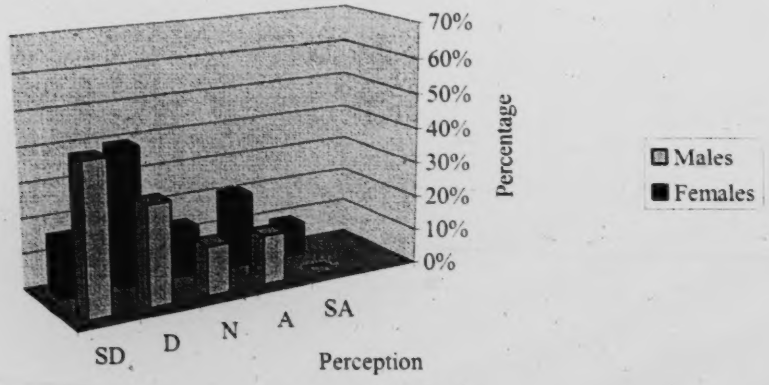


Figure 21: Comparison of Male and Female Teachers' Perceptions That It Was "Musty" in Classroom

As indicated, 72% of men and 56% of women either disagreed or strongly disagreed that the room was musty. Only 30% of women and 14% of men detected a musty odor in the classroom.

Of the respondents, no males or females agreed that classroom air was humid (Figure 22). The majority either disagreed or strongly disagreed that air was humid; 86% of men and 96% of women disagreed.

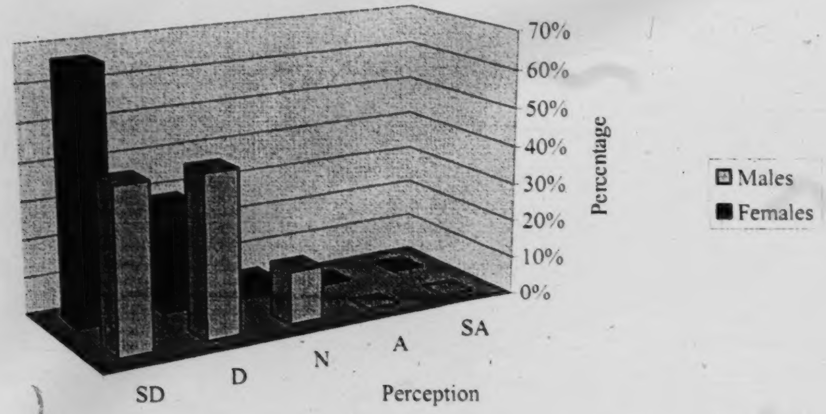


Figure 22: Comparison of Male and Female Teachers' Perceptions That It Was "Humid" in Classrooms

As expected from the humidity results, a large majority of respondents found classroom air to be too dry. Figure 23 illustrates this trend.

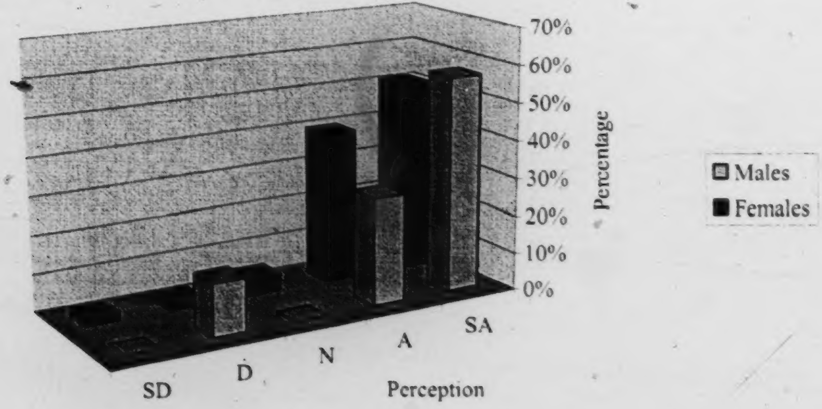


Figure 23: Comparison of Male and Female Teachers' Perceptions that it was "Dry" in Classrooms

As indicated in the figure, 86% of men and 91% of women agreed to some extent that classroom air was dry, not unexpected, given the typically dry outdoor conditions in Alberta along with the use of recycled air for indoor ventilation in the winter.

For purposes of clarification, "stuffiness" was defined on the questionnaire as "lacking sufficient ventilation". Responses to the question appeared varied, as indicated in Figure 24.

Approximately 29% of male and 34% of female respondents disagreed that classroom air was stuffy, while 71% of men and 49% of women agreed that the air was stuffy.

A paired sample t-test between male and female response data found no significant difference between male and female perception of environmental parameters. Results from the t-test are given in Appendix 31.

Given the potential biases involved in this study, results should be interpreted with caution. For example, assessment of human factors that might contribute to perception such as high stress levels, psychological factors and labor- management

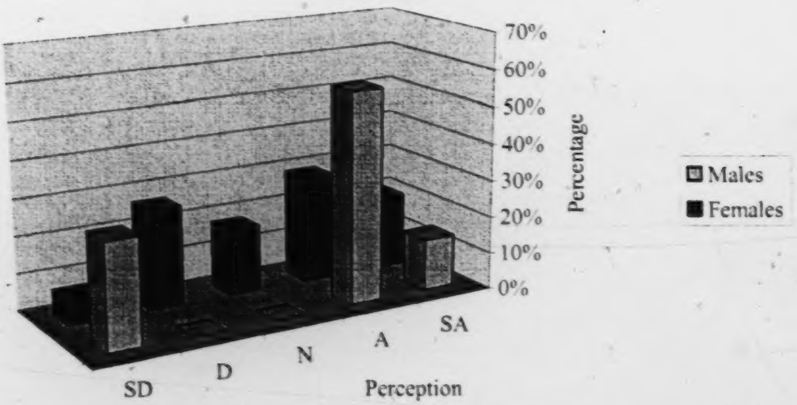


Figure 24: Comparison of Male and Female Teachers' Perceptions that it was "Stuffy" in Classroom.

relations was not done. In addition, confounders such as age and individual clothing insulation were not considered. For the future, a questionnaire that queried magnitude of perception (such as too cold, cold, neutral, hot or too hot) would be less ambiguous to the reader. Furthermore, categories of response would better correspond with measured air quality parameters.

5.7.2 Perception of Measured Parameters

Ordinal logistic regression (Minitab Inc., 2000) was used to compare perception results with environmental measurements from the winter sampling round. This statistical method requires that results from a Likert Scale be assigned ordinal values such as SA = 1, A = 2 etc. to enable comparison with measurements. Ordinal perception results are compared with RH, temperature and mould measurements in Appendix 33.

Past studies, such as those indicated in Section 2.5, have suggested relationships between environmental parameters and specific perceptions. For example, temperature has been related to perceptions of heat, dryness and stuffiness, and humidity and ventilation measurements have been compared with perceptions of dryness and stuffiness. Mould has been associated with the perception of mustiness.

Results from this study indicate no discernable relationships between measured IAQ parameters and perceptions of parameters. Table 21 illustrates p-values calculated for each comparison.

Table 21: Regression Between Perceived and Measured Environmental Parameters in Winter Sampling Round

Comparison (Perception: Measured Parameter)	Regression Coefficient	Calculated P-value
Dryness: Humidity	-0.058	0.57
Dryness: Temperature	0.033	0.87
Heat: Temperature	-0.20	0.32
Humid: Humidity	-0.062	0.56
Musty: Mould	-0.013	0.33
Stuffy: Temperature	0.10	0.62
Stuffy: Humidity	-0.058	0.53
Cold: Temperature	-0.10	0.61
Stuffy: Ventilation	-0.080	0.82
Dry: Ventilation	-0.38	0.37

Regression coefficient values given in Table 21 are between –0.38 and 0.10, suggesting that no significant relationships exist between IAQ measurements and perception of parameters. P-values above 0.05 reinforce that there is insufficient evidence to support an association between measured and perceived parameters.

While results from this study do not suggest a relationship between measured IAQ and human perception of the same parameters, investigation of this association should not be omitted from future studies. As mentioned earlier, perception may be confounded by a variety of factors including age, health, and social status. To accurately depict the relationship between measured and perceived parameters, confounding factors should be controlled for.

6.0 CONCLUSIONS

The intent of this investigation was to evaluate IAQ in Edmonton-area schools. Sampling was conducted in EPS, EIPS and EICS. Investigators visited schools during the fall and winter seasons and measured indoor comfort parameters as well as airborne mould concentration. Further to the gathering of physical data, investigators collected perception surveys from individual teachers.

The primary objective of the study was to establish baseline IAQ levels in school environments. While this objective was largely accomplished by Corinne Stocco and Mary Unobe, a summary of the baseline data served as the foundation for this thesis. Prior to correlational analysis, data distribution was evaluated. Figure 14 illustrates the non-normal distribution of airborne mould data justifying its subsequent nonparametric analysis. Further examination of seasonal airborne mould data revealed that the majority of winter data fell below the detection limit. Because non-parametric correlational analysis relies on robust data sets, airborne mould results from the winter sampling round were omitted. Baseline comfort parameter data is illustrated in Figures 17 and 18, showing normal yet differentiated distributions of seasonal data.

The second objective of the study was to establish if relationships existed between aerosol mould levels and selected IAQ parameters. No significant relationships were seen between airborne mould levels and environmental parameters, which included temperature, RH, ACH and occupancy. Although literature suggests that the parameters studied impact airborne mould levels, results may have been influenced by a variety of confounding factors. Furthermore, fluctuations in aerosol mould concentrations may not have been discernable within such a narrow range of temperature and RH measurements. Significant positive correlations were seen between outdoor and indoor mould levels, particularly for the major phylloplane moulds. This reinforces the theory that indoor aerosol mould levels will commonly reflect outdoor levels, likely due to the infiltration of outdoor propagules.

The third objective involved investigation of possible relationships between human perception and measured parameters of IAQ. Surveys queried teachers' perceptions of environmental conditions such as temperature, RH, ventilation and mustiness. A paired sample t-test revealed that there was no significant difference in response between genders. Furthermore, no correlation of perceived and measured environmental parameters was observed using ordinal logistic regression. While results from this investigation question the scientific credibility of perception data, it should be recognized that confounding factors, such as age and respondent health were not controlled for.

7.0 RECOMMENDATIONS

This investigation identified several topics for future research as illustrated below:

1. Accuracy of the results may have been compromised by the materials and methodology employed. For example, investigators used results from an RCS Plus® as an indirect representation of the level of mould in a classroom. However, because of the spatial and temporal variability of airborne mould particles, ACGIH does not recommend using air-sampling methodology to confirm the presence of mould (ACGIH, 1989). Mould levels in a room would be better characterized by an invasive investigation of walls and rugs, with air sampling as a means of secondary analysis.
2. The efficiency of the RCS Plus® varies according to the size of the mould particles. Furthermore, particles captured must be viable, and able to grow on the specific agar employed. Because of the selectivity of both the instrument and the agar, some of the moulds in the room may not have been captured. Combination of the RCS Plus® with a total count sampler, such as a gravity slide, would better illustrate the spectrum of airborne moulds in the room.
3. To augment the data obtained from this investigation, a future study might examine the duct systems of Edmonton-area schools. Because investigators were not able to incorporate duct traverses into the study, a significant source of air quality pollutants was neglected. Forthcoming investigations could focus exclusively on the condition of these passages.
4. A future investigation of indoor mould in Alberta could compare seasonal mould levels in summer and fall to ensure background levels of outdoor mould. This would limit the number of samples that were below the detection limit and would provide a more robust data set for statistical interpretation.
5. The Velocicalc Plus is typically used to conduct duct traverses, not at the diffuser level. By contrast, the Alnor Balometer was well equipped to measure airflow rate directly from diffusers of various sizes. However, it could not measure airflow rate from grilles. Future studies might employ an instrument

that is typically used to measure airflow rate at a diffuser and grille surface. The vane anemometer is frequently used for this purpose.

6. Throughout the study, investigators were inundated with requests for a baseline examination of other IAQ pollutants such as lead, asbestos and particulates. The overall picture of air quality in Edmonton-area school would benefit from a study addressing other air quality concerns.
7. Future study of associations between perceived and measured environmental quality should consider other confounders such as age and respondents health at the time of the surveying. This could involve a similar study but with preliminary screening to present a more accurate picture of the study participants.

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9.0 APPENDICES

Appendix 1: Airborne Mould Levels: Standards and Regulations of Various Organizations (Adapted From Rao and Burge, 1996)

Organization/Year	Recommendations
ACGIH (1995)	▪ Indoor levels < outdoor Levels ▪ <100 CFU/m^3 = acceptable ▪ 100-1000 CFU/m^3 = intermediate: eg. General indoor and outdoor concentrations ▪ >1000 CFU/m^3 = high: eg. animal handling areas
AIHA (1989)	▪ $\geq$ 1000 CFU/m^3 = indicates atypical situation ▪ High indoor/outdoor ratio = indoor amplifier present
Commission of the European Communities (1996)	▪ For houses: > 10^4 CFU/m^3 = very high < 10^4 CFU/m^3 = high < 10^3 CFU/m^3 = intermediate < 200 CFU/m^3 = low <50 CFU/m^3 = very low ▪ For non-industrial indoor: > 2000 CFU/m^3 = very high < 2000 CFU/m^3 = high < 500 CFU/m^3 = intermediate < 100 CFU/m^3 = low < 25 CFU/m^3 = very low
Canada Mortgage and Housing Corporation (CMHC) (1996)	▪ 0 CFU/m^3 = no action unless indicated by inspection ▪ $\geq$ 50 CFU/m^3 if one species = identify source to determine further action ▪ $\leq$ 150-200CFU/m^3 if several species = no action ▪ $\geq$ 200 CFU/m^3 if several species = requires further inspection ▪ $\leq$ 400-500 CFU/m^3 mainly *Cladosporium* and *Alternaria* = no action unless indicated by inspection

Organization/Year	Recommendations
National Health and Welfare (1993)	▪ Toxigenic, pathogenic mould not acceptable in indoor air ▪ ≥50 CFU/m^3 if one species = investigate ▪ ≤150 CFU/m^3 if mixture of species = OK ▪ ≤500 CFU/m^3 if common tree/leaf mould = OK in summer
WHO/IAQ (1988)	▪ Pathogenic and toxigenic mould unacceptable in indoor air ▪ >50 CFU/m^3 of one species = investigate ▪ ≤150 CFU/m^3 = OK if mixture of species ▪ ≤500 CFU/m^3 = OK if *Cladosporium* or other common phylloplane

Appendix 2: HREB Request for Ethics Review Form

SECTION A: GENERAL INFORMATION

A1. Project Title
Title of Project: *Indoor Air Quality in Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools*

A2. Applicant Information			
Name: Lorelei Betke, Corinne Stocco, Mary Unobe Title: Graduate Students Department: Environmental Engineering			
Mailing Address: #304, Environmental Engineering Building, University of Alberta			
City & Province: Edmonton, Alberta	Postal Code: T6G 2G7	Phone: 492-8548	Fax: 492-8289
E-mail Address:			
Signature:			Date:

A3. Co-Applicant Information			
Name: Dr. Warren Kindzierski Title: Assistant Professor Department: Environmental Engineering			
Mailing Address: #304, Environmental Engineering Building, University of Alberta			
City & Province: Edmonton, Alberta	Postal Code: T6G 2G7	Phone: 492-0247	Fax: 492-8289
E-mail Address: warren.kindzierski@ualberta.ca			
Signature:			Date:

A3. Co-Applicant Information			
Name: Steven Probert Title: Air Quality Specialist Department: Community Care and Public Health, Capital Health Authority			
Mailing Address: Suite 300, 10216-124 Street			
City & Province: Edmonton, Alberta	Postal Code: T5N 4A3	Phone: 413-7933	Fax: 482-5383
E-mail Address: sprobert@cha.ab.ca			
Signature:			Date:

A4. Authorizing Signature
Indication of Department Support for the Implementation of the Project.

Name of Dept. Chair, Assoc. Dean of Research, or Supervisor: Dr. Terry Hrudey	
Title: Professor and Chair of Civil and Environmental Engineering	
Signature:	Date:

A5. Co-Investigators / Thesis Committee		
Is this project for a graduate thesis? (√) Yes ( ) No If yes, please provide the names, departments, and phone numbers of your thesis committee.		
Name:	Department/Program:	Phone:
Warren Kindzierski	Environmental Engineering	492-0247
Selma Guigard	Environmental Engineering	492-8585
Jerry Leonard	Agricultural Food and Nutritional Science	492-0107

A6. Expedited Review	
If the study procedures are LIMITED to any of the following, please check (√):	
	Analysis of blood, urine, or any other biological specimen already collected.
	Examination of patient, medical, or institutional records.
	Modification of a previously approved protocol (specify title and approval date):
	Secondary analysis of data.
	Use of biological specimens normally discarded.

A7. Type of Investigation			
Which one of the following best describes the type of investigation proposed? Check (√) more than one if appropriate.			
	Clinical Trial		Multi-centre Trial
	Drug Study		Pilot Study
	Epidemiological Study		Qualitative Study
	First Application in Humans		Technology Assessment / Development
	Sequel to Previously Approved Project (specify title and approval date):		
√	Other (specify): Indoor Air Quality Study.		

A8. Site of Research	
Where will the research be conducted? Check (√) more than one if appropriate. Specify the area/department/program.	
Alberta Cancer Board Sites:	
	Cross Cancer Institute:

Capital Health Authority Sites:	
	Community Care and Public Health:
	Glenrose Rehabilitation Hospital:
	North Edmonton Community Health Centre:
	Royal Alexandra Hospital:
	Stollery Children's Health Centre:
	Sturgeon Community Hospital and Health Centre:
	University of Alberta Hospital:
Caritas Health Group Sites:	
	Edmonton General Hospital:
	Grey Nuns Community Hospital and Health Centre:
	Misericordia Community Hospital and Health Centre:
University of Alberta Sites:	
	Specify (e.g. Corbett Clinic):
Other:	
√	Specify: Schools within Capital Health Region and under the jurisdiction of Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools.
Letters of Support:	
( ) Pending (√) Attached ( ) Not Applicable	

A9. Funding / Budget	
How is the project funded? Please check (√) the appropriate box.	
√	Funding approved; specify source(s): Edmonton Community Lottery Board and Strathcona Community Lottery Board.
	Funding pending; specify source(s):
	No external funding required.
Budget	

√	Please check here (√) that you have attached a budget summary. The summary must include details of investigator payments and recruitment incentives (if present). Please attach the budget as an appendix to the form.

A10. Remuneration	
Are any of the investigators involved receiving any directs personal remuneration or other personal or family financial benefits (either direct or indirect) for taking part in this investigation?	
√	Yes. If so, append a letter detailing these activities. Please attach this letter to your budget summary.
	No.

A11. Safety Approvals					
Please check (√) whether or not this study requires any of the following safety approvals. If a safety approval is needed, please indicate whether the approval documentation is pending or attached as an appendix to this form.					
Biohazardous Materials:					
√	Not Applicable		Pending		Attached
Electromechanical:					
√	Not Applicable		Pending		Attached
Health Protection Branch or Other Canadian Federal Agency:					
√	Not Applicable		Pending		Attached
Radiation:					
√	Not Applicable		Pending		Attached

SECTION B: DETAILS OF PROJECT

Description of the Project

B1. Provide a clear statement of the purpose and objectives of the project.

Indoor environmental quality (IEQ) refers to physical, chemical and biological characteristics of the indoor environment (Project Proposal, 2000) and includes parameters such as lighting levels, noise, health and safety as well as indoor air quality (IAQ). Capital Health Authority, Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools are in partnership with the University of Alberta to investigate IAQ in schools in the Capital Health Region. The purpose of this two-year study is to determine the status of mould in schools so that responsible authorities may develop an IAQ management plan. The specific IAQ parameters this study investigates are fungi, carbon dioxide, carbon monoxide, temperature, relative humidity, and ventilation rates.

The investigation of indoor air quality in schools within the Capital Health

Region arose for several reasons. First, literature states that school IAQ affects student health. Second, Health Canada's Environment Health Directorate recommended that Canadian research initiatives be implemented to establish baseline levels of fungal contamination within public buildings (Env. Health Directorate, 1995). Third, some schools in the Capital Region have had IAQ problems, including the presence of mould. And fourth, there is public pressure with respect to school IAQ, fuelled by parental and media attention (Project Proposal, 2000).

Many studies have already investigated IAQ in schools across North America and Europe, and this needs to be investigated in the Edmonton area. Since it is impossible to generalize the results of IAQ studies over geoclimatic regions, a study in the mostly cool and dry Edmonton area, supporting a different fungi population, is required. There are four main research objectives in this study to determine presence of fungal contaminants in schools:

- Develop local procedures and protocols for identifying, evaluating, and managing fungal contaminants in schools.
- Identify parameters and conditions that contribute to fungal growth in schools.
- Determine baseline levels and types of school fungal contaminants as well sa associated indoor air quality parameters.
- Develop cost effective fungal prevention and remediation strategies.

B2. State the hypotheses and/or research questions.

What is the state of IAQ within schools in the Capital Health Region?
What are the types and concentrations of fungi in the Capital Health Region schools?
What conditions facilitate fungal growth?

B3. Briefly summarize past human and/or animal research that has lead to this project.

Background

There are approximately 10 000 known species of fungi, and 2000 new species are identified each year (Miller, 1992). Fungi's quick and asexual reproduction cycle results in the formation of an enormous quantity of spores (Gravesen, 1979). Fungi are heterotrophic and their food demands range over a broad spectrum of organic materials (Gravesen, 1979). In the context of this research, fungi are mainly mesophilic with an optimal temperature for growth between 20-40C, and prefer more acidic conditions around pH 5-6 (Gravesen, 1979). most spores in indoor air originate from the outdoors, (Pasanen, 1992) and readily enter by circulating through doorways, windows, and heating, ventilation and air-conditioning (HVAC) systems (American Academy of Pediatrics, 1998). Fungus can grow on virtually any substrate including: glass, paint, rubber, textiles, electrical equipment, and organic material such as paper, cardboard, ceiling tiles and wood products (Miller, 1992). There are three main factors that contribute to their growth: sufficient water, mild temperatures, and organic nutrient.

Adverse health effects

Between 6-15% of the Canadian population is allergic to fungi (Miller, 1992). Whether or not people exposed to fungi develop symptoms depends on the nature of the fungal material, the amount of exposure, and the susceptibility of exposed persons (NY Dept of Health, 2000). Susceptibility varies with genetic predisposition, age, and state of health (NY Dept of Health, 2000). Fungi are frequently implicated in environments with poor indoor air quality and are associated with increased fatigue, concentration of difficulties, headaches, eye, skin and throat irritation, increased frequency of common colds, wheeze and skin sensitization (Whillans, 1995). Risk of flu symptoms, diarrhoea, dermatitis, malaise, epistaxia, hypersensitivity pneumonitis, and fever also increases in those exposed to mould (Health Canada, 1995). Fungal infections may also occur in the immunosuppressed (Miller, 1992).

Indoor Air Quality Guidelines

Numerous authors maintain that a tolerable exposure to mould spores in indoor air ranges from 100-1000 CFU/m^3 (colony forming units). National Health and Welfare Canada suggests that up to 150 CFU/m^3 in government office buildings is acceptable if there is a mixture of species reflective of the outdoor air spores. In the summer time, 500 CFU/m^3 is acceptable if the species present are primarily tree and leaf fungi. Otherwise, a level of 50 CFU/m^3 for individual species of fungi is deemed acceptable indoors (Health Canada, 1995). Currently in Canada, no limits or standards for IAQ in schools exists.

Literature

Literature states that schools are more likely to experience IAQ deterioration due to:

- Aging facilities;
- Deterioration of the efficiency of the heating, ventilation and air-conditioning system;
- Insufficient maintenance of schools;
- Life expectancy of facilities such as portables being exceeded;
- Construction of more tightly sealed buildings;
- Use of synthetic building materials.

B4. Describe the numbers and type(s) of subjects to be included. If appropriate, specify the number of subjects in each study group. Provide a rationale for the sample size and include sample size calculations where appropriate.

There are a total of 261 schools within the Capital Health Region. It is commonly known in statistics that, in order for the results of an experiment to approach a normal distribution, a sample size equal to or greater than 30 must be obtained. Due to budgetary and time constraints, a sample size of 40 was chosen. To be representative of the whole school population, these 40 schools will be selected via stratification and random sampling techniques. Using parametric statistical analysis, the results from the sample will be applied to all schools within the Capital Health Region, thus allowing the investigators to answer the previously stated research questions (please refer to question B2).

The schools will be stratified into two levels:
Geographic location
Episodes of water damage and/or fungal growth

Stratifying the schools into geographic location allows for all school boards to be proportionally represented within the Capital Health Region. By stratifying by episodes of water damage and/or fungal growth, it will be possible to sample in schools that have had these problems, and those that have not. other parameters, such as age of initial construction and school building will be captured via random sampling.

Within selected schools, there will be a representative number of classrooms selected. Classes will be selected by using the results obtained from the Screening Survey (please see attachment #9). In this document, the schools will provide the different phases of construction on a schematic, which will allow for selection of rooms. Currently, the details of the experimental design are still under development with a University of Alberta statistician.

B5. List any subject inclusion/exclusion criteria.

Not Applicable. All schools within the Capital Health Region have an equal chance of being randomly selected for the study.

B6. Please check (√) if any of the subjects who will be recruited fall into one or more of the following categories:	
	Under 18 years of age
	Cognitively Impaired
	Residing in institutions (e.g. prison, extended care facility)
	Students
	Employees of researchers' organization
	Have language barriers (e.g. illiterate, not English-speaking, dysphasic)
	In another country

Description of Research Procedures

B7. Provide a summary of the design and procedures of the research. Provide details on the methods of data collection and data analysis, time commitment for the subjects etc. Please note that any and all study measures need to be appended to the copies of the research / grant proposal (e.g. questionnaire, interview guides, rating scales etc.).

Data Collection:

Questionnaires as well as visual inspection will be used to obtain information regarding the school maintenance history, central HVAC system and the room to be sampled (See attachment #10, 11, 12).

Pre-Screening Survey
General characterization of schools
Currently being used for experimental design purposes
Completed by school facilities personnel
Estimated completion time of one hour

Screening Survey
Provides information regarding the different phases with respect to construction type, water damage, building materials etc. This will enable the subsequent selection of rooms to be sampled.
The questionnaire is self-applied and will be completed by the school facility personnel.
Estimated completion time of half an hour.

School Maintenance History Survey
Determine episodes of water damage and recent renovations/upgrades in the school. Maintenance of school mechanical systems will also be assessed and general health of the school population evaluated.
Self-applied
completed by school facility personnel
Estimated completion time of one hour, pilot test pending

Central HVAC Survey

Assesses the general condition of the central HVAC
Inspection and interview
Completed by field investigator with the assistance of a facility personnel and the school custodian.
One completed for each central HVAC system
estimated Completion time of one hour, pilot test pending

Room Survey
investigate the indoor air quality of individual rooms.
Self-applied
Completed by a field investigator
Estimated completion time of one hour, pilot test pending

School selection:
Experimental design will be based on a stratified sampling approach. For a summary of statistical design, please refer to B4.

Data analysis:
Parametric statistical analysis
Correlate measured results (CO, CO_2, temperature, humidity, fungal count) and survey data

Procedure of Research:

Awareness campaign (pretest):

There will be a press release one day prior to the sampling date informing the public of the study, the participating parties and a brief description of the activity that will ensue.
Information sheet will be forwarded to parents in September and reminders will be issued for subsequent sampling rounds.
Introductory letter and information sheet to the principal of the selected schools will be faxed by August 31, 2001. This will be followed up by a phone call to further discuss the letter and where necessary a meeting between the field investigators and the principal can be arranged to further clarify any issues. The commitment and assistance of the principal will be subsequently sought and obtained. Up to ten principals may choose not to participate without compromising the integrity of the experimental design.

Field procedures will be divided into round one (September/October), round two (December/January) and round three (February/March 2002). The activities of round two and three will be a repetition of round one in the different selected schools.

Procedures of each round:
Upon receipt of response forms an appointment is made with participating schools. Confirmation of appointment is made by telephone one day before the sampling date.

Field investigators arrive in selected school at prescheduled time and meet with the school contact, facilities services contact and head custodian.
A field investigator with assistance of facilities personnel and the head custodian will complete HVAC survey.
Sampling location is confirmed from schematic and samplers are deployed to the location inside and outside as per sampling protocol (see attachment #13)
The visit is completed in half a day with one hour spent in inspection with the assistance of the facility personnel and a sampling period of about 20 minutes in each room.
Samples are transported to the Provincial Public Health Laboratory for analysis.

Air sampling and analysis equipment:

The following air samplers will be used for both indoor and outdoor sampling:

RCS plus handheld sampler with Rose Bengal Agar will be used for mould sampling.
Q-trak will be used for the measurement of CO, CO_2, temperature and relative humidity
Velocicalc plus air velocity meter will be used for measurement of air flowrate.

Laboratory Analysis:

Incubate sample for 7 days at 28-30C
Identify mould species using microscopic mount and count the mould colonies observed.

Questionnaires (attachments 8,9,10,11,12):

Prescreening, Screening, School Maintenance History, HVAC, and Room Surveys

B8. Which treatments or procedures are additional to those required for standard patient care?
Not Applicable.

B9. If the procedures include a blind, under what conditions will the code be broken and what provisions have been made for this? Who will have the code?
Not Applicable.

Obtaining Consent

B10. Clearly detail who will be recruiting subjects and obtaining consent, and the procedures for doing this. If appropriate specify whether subjects will be randomly assigned to groups before or after consent has been attained.

On behalf of Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools, school superintendents have agreed to participate in this study. Facilities services personnel will be asked to complete a consent form before participating in onsite HVAC investigations. In addition, school principals will be asked to compete a consent form on behalf of their schools. Consent forms will be mailed to schools three weeks prior to scheduled sampling times. Schools will be randomly assigned to groups before consent has been obtained from facilities personnel and principals.

B11. Specify methods for dealing with groups identified in #B6. If the subjects are not able/competent to give fully informed consent, who will consent on their behalf?

Not Applicable.

B12. If the subjects will be offered compensation for participating in the research, provide details. Specify the amount, what the compensation is for, and how payment will be determined for subjects who do not complete the study.

Not Applicable.

B13. Do any of the procedures include the use of deception or partial disclosure of information to subjects?

No.

If yes, provide rationale for the deception or partial disclosure. Describe the procedures for (a) debriefing the subjects and (b) giving them a second opportunity to consent to participate after debriefing.

Not Applicable.

Recruitment Aids/Information Letters/Consent Forms					
B14. Are you planning to use any recruitment aids such as posters, newspaper advertisements, radio announcements, or letters of invitation? If so, please indicate the reading level of each aid and check (√) if it has been attached to the form as an appendix.					
Recruitment Aid #1 – Specify (e.g. poster, letter etc.):					
√	Not Applicable		Reading Level		Attached
Recruitment Aid #2 – Specify:					
√	Not Applicable		Reading Level		Attached
Information Letter #1 – Information letter to principle.					
	Not Applicable	12	Reading Level	√	Attached
Information Letter #2 – Information sheet for parents.					
	Not Applicable	9.2	Reading Level	√	Attached
Consent Form #1 – Consent form for school principals					
	Not Applicable	12.0	Reading Level	√	Attached

Consent Form #2 – Consent form for facilities services personnel

	Not Applicable	11.4	Reading Level	√	Attached

B15. What steps have been taken to make the recruitment aids, information letters, and consent forms comprehensible to the person(s) giving consent?

Information documents were reviewed by investigators and the Steering Committee (including representatives of Capital Health Authority, Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools). Grade levels were determined using Word v.7.0 Grammar check.

Risks and Benefits

B16. What are the benefits of the proposed research for the subject and/or for scientific knowledge in general?

The Capital Health Authority believes that this project will allow for enhancement of the local community's quality of life through better health for school children. Some of the community benefits include:

- Reducing the number of sick days, thereby decreasing the financial burden on the healthcare and education systems;
- Healthier children and teachers
- Proactive school IAQ management
- Improved public awareness about IAQ
- Status of IAQ within individual schools, and overall in Capital Health Region

B17. What adverse effects may result from the research? How will adverse effects be dealt with? Please note that adverse effects are not limited to physical risks, but include psychological, emotional, and spiritual risks as well.
There are no anticipated health or safety risks.

Privacy and Confidentiality

B18. What steps will be taken to respect the privacy of the subjects and protect confidential data?

This study will not call for personal information from students or staff. Information provided will be kept for at least five years in a secure area. All information will be held private, except when professional codes of ethics or legislation requires reporting.

B19. Identify any agencies or individuals who will have access to confidential data now or in the future.
Individuals: investigators, thesis committee
Agencies: Capital Health, Edmonton Public School Board, Elk Island School Board, Elk Island Catholic School District

Appendix 3: Letter from HREB

Health Research Ethics Board

biomedical research
212.27 Walter Mackenzie Centre
University of Alberta, Edmonton, Alberta T6G 2R7
p.780.492.9724 f.780.492.7303
ethics@med.ualberta.ca

health research
1-492 Corbett Hall, University of Alberta
Edmonton, Alberta T6G 2G4
p.780.492.0839 f.780.492.1026
ethics@www.rehabmed.ualberta.ca

July 18, 2001

Ms. Lorelei Betke, Ms. Corinne Stocco, & Ms. Mary Unobe
304 Environmental Engineering Building
Department of Environmental Engineering

Dear Ms. Betke, Ms. Stocco, & Ms. Mary Unobe,

Re: Indoor Air Quality in Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools.

Thank you for presenting the above study to the Health Research Ethics Board (B: Health Research) at the meeting of July 6, 2001. The board members appreciated the opportunity to learn of the research you are planning to conduct and to provide comments.

The board discussed the nature of your project following the meeting, and determined that the project did not need to come to our board for ethics review and approval since the focus of your study does not involve human subjects, but rather environmental samples. If this project should lead to further research which would involve human subjects in some format (e.g. questionnaire, interviews, human samples), then that research would need to receive review and approval from our board. We would welcome your returning at that time.

On behalf of the Health Research Ethics Board (B: Health Research), I wish you every success in your research endeavors.

Sincerely,

Sharon Warren

Dr. Sharon Warren
Chair, Health Research Ethics Board (B: Health Research)

cc: Dr. Warren Kindzierski
Mr. Steven Probert

University of Alberta

Capital Health

CARITAS HEALTH GROUP

Appendix 4: Study Population

EPSB	EPSB	EIPS	EICS
Abbott	Meadowlark	Ardrossan Elementary	Arch Bishop Jordan
Academy at King Edward	Mee-Yah-Noh	Ardrossan Jr/Sr High	Father Kenneth Kearns
Afton	Menisa	Bev Facey Community	Holy Redeemer
Aldergrove	Meyokumin	Brentwood	Jean Vanier
Allendale	Meyonohk	Campbelltown	Madonna
Athlone	Michael A. Kostek	Clover Bar	Our Lady of Perpetual Help
Avalon	Minchau	Colchester	St. Luke
Avonmore	Montrose	F.R. Haythorne	St. Theresa
Balwin	Mount Pleasant	Fultonvale	
Bannerman	Mount Royal	Glen Allen	
Bataryn	Newton	Mills Haven	
Beacon Heights	North Edmonton	Ministik	
Belgravia	Northmount	Pine Street	
Bellevue	Norwood	Salisbury	
Belmead	Old Scona Academic	Sherwood Heights	
Belmont	Oliver	Uncas	
Belvedere	Ormsby	Wes Hosford	
Bisset	Ottewell	Westboro	
Brander Gardens	Overlanders	Woodbride Farms	
Brightview	Parkallen	Wye	
Britannia	Parkdale		
Brookside	Parkview		
Caernarvon	Patricia Heights		
Calder	Pollard Meadows		
Callingwood	Prince Charles		
Capilano	Princeton		
Centennial	Queen Elizabeth		
Clara Tyner	Queen Mary Park		
Coronation	R. J. Scott		
Crawford Plains	Richard Secord		
Crestwood	Rideau Park		
D. S. MacKenzie	Rio Terrace		
Daly Grove	Ritchie		
Dan Knott	Riverbend		
Delton	Riverdale		
Delwood	Ross Sheppard		
Dickinsfield	Rosslyn		
Donnan	Rundle		

EPSB	EPSB	EIPS	EICS
Duggan	S. Bruce Smith		
Dunluce	Sakaw		
Earl Buxton	Satoo		
Eastglen	Scott Robertson		
Eastwood	Sherbrooke		
Edith Rogers	Sherwood		
Ekota	Sifton		
Ellerslie Campus	Spruce Avenue		
Elmwood	Steele Heights		
Evansdale	Steinhauer		
Forest Heights	Strathcona		
Fraser	T. D. Baker		
Fulton Place	Talmud Torah		
Garneau/Queen Alexandra	Terrace Heights		
George H. Luck	Thorncliffe		
Glendale	Tipaskan		
Glengarry	Velma E. Baker		
Glenora.	Vernon Barford		
Gold Bar	Virginia Park		
Grace Martin	W. P. Wagner		
Grandview Heights	Waverley		
Greenfield	Weinlos		
Greenview	Wellington		
Griesbach	Westbrook		
Grovenor	Westglen		
Hardisty	Westlawn		
Harry Ainlay	Westminster		
Hazeldean	Westmount		
High Park	Windsor Park		
Highlands	Winterburn Westview		
Hillcrest	Woodcroft		
Hillview	York		
Holyrood	Youngstown		
Homesteader			
Horse Hill			
Inglewood			
J. A. Fife			
J. Percy Page			
James Gibbons			
Jasper Place			
John A. McDougall			

EPSB			
John Barnett			
John D. Bracco			
Julia Kiniski			
Kameyosek			
Kate Chegwin			
Keheewin			
Kenilworth			
Kensington			
Kildare			
Killarney			
King Edward			
Kirkness			
L. Y. Cairns			
L'Académie Vimy Ridge			
Lago Lindo			
Lansdowne			
LaPerle			
Lauderdale			
Laurier Heights			
Lawton			
Lee Ridge			
Lendrum			
Londonderry			
Lorelei			
Lymburn			
Lynnwood			
M. E. LaZerte			
Malcolm Tweddle			
Malmo			
Mary Butterworth			
Mayfield			
McArthur			
McCauley			
McKee			
McKernan			
McLeod			
McNally			

Appendix 5: Sample Schools

Legend for Table:

EPS	Edmonton Public Schools
EIPS	Elk Island Public Schools
EICS	Elk Island Catholic Schools

EPS	EIPS	EICS
Belgravia	Colchester	Holy Redeemer
Clara Tyner	F.R. Haythorne	Jean Vanier
Coronation	Cloverbar	Our Lady of Perpetual Help
Crestwood	Pine Street	Archbishop Jordan
Duggan	Salisbury	
Eastglen	Westboro	
Eastwood	Woodbridge Farms	
Elmwood		
Fraser		
Glendale		
Harry Ainlay		
John D. Bracco		
Julia Kiniski		
Lauderdale		
Laurier Heights		
Lorelei		
McCauley		
McKernan		
McNally		
Mee-Yah-Noh		
Menisa		
Newton		
Ottewell		
Rio Terrace		
Riverbend		
Ross Shepard		
Sakaw		
Satoo		
Sifton		
Tipaskan		
Wellington		
Windsor Park		

Appendix 6: Proportional Allocation of Schools into Two-Level Strata

No Water Damage and/or Mould Investigation						
NW/NC/N	Fraser	Newton	Eastwood	Sifton	Eastglen	
C	Mee-Yah-Noh	Wellington	Lauderdale			
W	Ross Sheppard	Rio Terrace	Coronation	Glendale		
SC	Belgravia	Ottewell	Windsor Park	Clara Tyner	McKernan	
SW/SE	Julia Kiniski	Harry Ainlay	Sakaw	Tipaskan	Satoo	Riverbend
EIPS	Cloverbar	Colchester	Westboro			
EICS	Jean Vanier					
Water Damage and/or Mould Investigation						
NW/NC/N	Lorelei	John D. Bracco				
C	McCauley					
W	Laurier Heights	Crestwood	Elmwood			
SC	McNally					
SW/SE	Menisa	Duggan				
EIPS	F.R. Haythorne	Salisbury	Woodbridge Farms	Pine Street		
EICS	Arch Bishop Jordan	Our Lady of Perpetual Help	Holy Redeemer			

Appendix 7:Cross-Tabulation Results

School * Geographical Region * Utilization Rate * Mould Investigation

Mould Investigation	Utilization Rate	Geographical Region					
		NW	C	NE	SW	SE	Elk Isle
Yes	0-60.3 (low)	2	4	3	3	1	0
	60.4-83.5 (medium)	0	3	1	3	2	1
	83.6-180 (high)	3	3	0	3	1	1
No	0-60.3 (low)	7	33	7	8	5	1
	60.4-83.5 (medium)	15	16	5	7	12	7
	83.6-180 (high)	2	16	3	13	11	18

School * Geographical Region * Utilization Rate * Water Damage

Water Damage	Utilization Rate	Geographical Region					
		NW	C	NE	SW	SE	Elk Isle
Yes	0-60.3 (low)	1	3	3	1	1	1
	60.4-83.5 (medium)	4	1	0	1	2	3
	83.6-180 (high)	2	1	1	0	3	11
No	0-60.3 (low)	8	34	7	10	5	0
	60.4-83.5 (medium)	11	18	6	9	12	5
	83.6-180 (high)	3	18	2	16	9	8

School * Geographical Region * Utilization Rate * Building Type

		Geographical Region					
Does school have portables?	Utilization Rate	NW	C	NE	SW	SE	Elk Isle
Yes	0-60.3 (low)	2	0	2	2	3	0
	60.4-83.5 (medium)	3	9	5	5	13	5
	83.6-180 (high)	3	7	2	12	10	14
No	0-60.3 (low)	7	37	8	9	3	1
	60.4-83.5 (medium)	12	10	1	5	1	3
	83.6-180 (high)	2	12	1	4	2	5

Appendix 8: Schools Assigned to Each Subset

Between Structures	**Within Structures**	**Within Space**	**Seasonality**	**Between Instruments**	**CO_2 Decay**
Menisa	Arch Bishop Jordan	Glendale	Satoo	Riverbend	Lauderdale
Lorelei	Laurier Heights	Newton	Mee-Yah-Noh	Salisbury	Menisa
Clara Tyner	Lorelei	McCauley	Duggan	Sifton	Elmwood
Crestwood	Ross Sheppard	Harry Ainlay	Salisbury	Glendale	Duggan
John D. Bracco	Sakaw	McKernan	Laurier Heights		Eastglen
Julia Kiniski	Salisbury	Ottewell	Our Lady of Perpetual Help		Riverbend
Sakaw	Sifton	Cloverbar	Julia Kiniski		Tipaskan
Sifton	Tipaskan	Wellington	Fraser		Windsor Park
Westboro		Colchester	Riverbend		
			Coronation		

Appendix 9: Sampling Protocol

Capital
Health

Environmental Health Services

UNIVERSITY OF ALBERTA
Civil and Environmental Engineering

FIELD INVESTIGATION SAMPLING PROTOCOL

Title of Project: *Indoor Air Quality in Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools.*

Principal Investigators:

Steven Probert Capital Health (780) 413-7933	Warren Kindzierski University of Alberta (780) 492-0247

Co-Investigators:

Lisa Johnston Edmonton Public Schools (780) 429-8132	Dale Lechelt Elk Island Public Schools (780) 417-8125
Arjen DeVries Elk Island Catholic Schools (780) 991-1340	

Field Investigators:
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University of Alberta
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Introduction

This section outlines the general field investigation and sampling protocols. Specific details regarding instrument calibration and sampling procedures are contained in the standard operating procedures for each instrument. Three instruments, namely the Biotest Hycon RCS Plus® fungal sampler (Model 940310), the TSI Q-Trak® air quality meter (Model 8551) and the TSI Velocicalc® air velocity meter will be used for sampling. The RCS Plus® will be used to establish baseline fungal levels within sampling locations. 6-minute samples will be taken and then analyzed at the Provincial Mycological Laboratory. The Q-Trak® will be used to measure CO_2, CO, relative humidity and temperature. Values of CO_2 obtained will be used for comparative analysis with established standard such as ASHRAE. Ventilation rates can also be determined from CO_2 decay measurements. The Velocicalc® plus will be used to establish air flowrate measurements into the OAI as well air velocity from the diffusers located in the classrooms. Outdoor measurements with all three instruments will serve as a control for the indoor measurements in order to confirm the indoor air quality of the rooms.

GENERAL

1.0 Documentation
1.1 Photograph rooms being sampled and areas of noticeable fungal contamination for reference and documentation purposes.
1.2 When completing the room survey, note number of room occupants, and describe potential interferences to air sampling and where they are located (eg. distance of heat sources to instruments and distance of instruments from occupants).
1.3 Store all records in a secure location (pictures, Q-Trak® measurements, surveys).

2.0 QA/QC Procedures and Calibration
2.1 Sample during normal classroom hours.
2.2 Calibrate all three instruments (Q-Trak®, Velocicalc®, RCS Plus®) prior to sampling.
2.3 Calibrate RCS Plus® once per month.
2.4 Conduct one field blank per week for fungal samples only. Collect field blanks by placing the agar strip in the RCS Plus® and immediately removing it for laboratory analysis. The RCS Plus® sampler must not be operational during this procedure.
2.5 Conduct one replicate of RCS Plus® sample per school.```
2.6 Decontaminate RCS Plus® sampler once per week in sterile environment.
2.7 Include Chain of Custody forms with all fungal samples submitted for laboratory analysis.
2.8 Store Rose Bengal Agar (RBA) strips in a refrigerator. Keep strips away from direct heat or sunlight. RBA strips have a shelf life of 2 months.

INDOOR INVESTIGATION AND SAMPLING PROTOCOL
Fill out IAQ advisory sheet if the ASHRAE threshold levels for CO_2 are exceeded as well as if potential hazardous conditions exist.

3.0 HVAC Investigation
3.1 Investigate ventilation system and complete the HVAC survey with facility contact personnel.
3.2 Make certain that the fans are shut down so that close & safe observation of filters and coils can be made.
3.3 If there is evidence of mould growth, take a sample according to section 5.0 for analysis by the Provincial Public Health Laboratory.

4.0 Visual inspection in selected rooms
4.1 Fill out the room survey. If mould growth is visible, obtain a tape sample according to section 5b for analysis by the Provincial Public Health Laboratory.

Take a picture of the room from the door.

5.0 Fungal Sampling

5a Water Samples (e.g., Humidifier reservoir)

5.1a If pooling of water is noticed, collect a sample in a specimen bottle for laboratory analysis.

5b Surface Samples – Clear adhesive-tape sampling[i]

When mould is suspected, follow the steps below:
5.1b Use latex gloves when handling tape.
5.2b Label the wax paper upon which the tape will be placed with a Sharpie pen, indicating identification number. Enter the date, time, school, phase, room, and identification number into a logbook.
5.3b Remove a 3 inch strip of tape from the dispenser. Handle tape by edges only.
5.4b Collect sample by gently touching the tape to a test surface and removing the tape with a slow, steady force. A sufficient sample will appear as a light deposit on the tape. Samples with too heavy a deposit will be difficult to examine by microscope and should be discarded into biological waste container. Make note of areas where wall is porous and tape sample is difficult to obtain.
5.5b Take one blank on the first sampling day per week and submit this to the Provincial Public Health Laboratory.
5.6b Following sample collection, attach tape strips to wax paper (avoiding creases and folds).
5.7b Dipose of used latex gloves after each sample, placing them in a biological waste container.
5.8b Lay the wax paper flat in a Ziploc bag, then into the cooler for transportation to the Provincial Public Health Laboratory.

6.0 Air sampling using RCS Plus®[ii,iii,iv,v]

6.1 Don clean pair of disposable gloves.
6.2 Remove impeller drum and disinfect with isopropyl alcohol. Allow drum to dry.
6.3 Mark each agar strip blister pack with a unique sampling number using a Sharpie pen. 6.4 Handle agar strips by edges only. If agar is touched, strip should be discarded.
6.5 Peel back wrapper on agar strip by about 4cm and remove the agar strip. Inspect for any growth or contamination. Discard if any visible growth is observed.
6.6 Insert agar strip into the RCS Plus® impeller assembly with agar surface facing towards the impeller blades until impeller drum is completely enclosed and the grip tab of the agar strip protrudes by about 2cm.
*6.7 Place the RCS Plus® on a tripod, 3.3 ft (1 m) off the floor, near the center of the room, orient with impeller blades facing upwards towards the ceiling.
6.8 Turn instrument on to standby mode and check battery power. If battery power becomes insufficient during sampling the samples must be discarded.
6.9 Collect six-minute air samples with a sample volume of 300 L as recommended by Health Canada guidelines.

6.10 Using the grip tab, remove the agar strip from the RCS Plus® impeller assembly, and place the strip back into its blister pack, nutrient surface facing downwards.

6.11 Seal sides of the blister pack with tape (being careful not to cover identification label), and place the sample into a Ziploc freezer bag.

6.12 Up to 10 agar strips in sealed blister packs can be placed into one Ziploc bag.

6.13 Ziploc bags should be returned to a dark container as soon as possible after sampling. Rose Bengal agar is fungicidal with prolonged exposure to light.

6.14 After each sample, disinfect the RCS Plus® impeller with isopropyl alcohol & air-dry.

6.15 Upon completion, place the RCS Plus® back into its carrying case.

6.16 Deliver all samples to the Provincial Public Health Laboratory within 24 hours.

*If investigating within space variability, repeat steps 6.1 to 6.14 for the following locations:

- 1m away from the main door and 1m to the right (If a wall is directly to the right, place RCS Plus® 1m away to the left).
- 1m away from center of wall opposite from door

7.0 TSI Velocicalc®

7.1 Using smoke tubes, determine if vent is supply or return. Note in logbook.

7.2 Place Velocicalc® about 1" on the edge of the diffuser and perpendicular to the direction of air flow in order to obtain an accurate estimate of the flow rate of the incoming air from the duct.

7.3 To measure airflow rate, expose the sensor window on the Velocicalc® with the orientation dimple facing upstream of the air current.

7.4 Collect replicate flow rate measurements from multiple locations in space served by each air supply diffuser or vent according to the table below:

Vent Type	**Number of Measurements**	Location of Measurement
Square diffuser	4	Middle plaque, center of side
Round diffuser	4	Middle cone, equally spaced
Rectangular grille (small - medium)	Varies	Middle of each 6" x 6" square
Rectangular grille (large)	Varies	Middle of each 12" x 12" square

8.0 TSI Q-Trak® Air Quality Monitor (Model 8551)

8.1 Two Q-Trak®s will be used to sample randomly selected rooms. One will be used for an 8-hour measurement, the other will be used to obtain spot measurements of humidity, temperature, CO and CO_2. *Both Q-Trak®s will also be used to sample CO_2 decay in an unoccupied location over 2 hours.

ᵞ8.2 For spot measurements, record data for 15 minutes. Place the Q-Trak® 1m away from the main door and 1m to the right. If a wall is directly to the right, place the Q-

Trak® 1m away to the left. Ensure that the Q-Trak® is placed 6.6 ft (2m) away from any occupant and in an area of the room where it will not be directly impacted by vents, dust, cold or heat sources. If this is not possible, note interferences in logbook.
8.3 Secure the Q-Trak® instrument to sampling location with duct tape at an approximate height of 1m.
8.4 Record the locations of the Q-Trak® in the logbook.
8.5 If possible, take measurements during periods of peak occupancy.
8.6 Record peak average values for each parameter after the sample period into the logbook. An interval of 15 minutes compares with ASHRAE standards at a height of 3.3ft (1m).
8.7 For the 8-hour sample, make certain that instrument is running off of A/C and not batteries. Furthermore, secure the handheld portion of the Q-Trak® into the briefcase, and secure the briefcase to a non-moveable object (ie. Filing cabinet, desk).
8.8 Download information from Q-Trak® onto a computer at the end of the day.
*For CO_2 decay subset, place the Q-Trak®s in 2 unoccupied classrooms according to instructions in section 8.2. Record CO_2 data for 2 hours. Ensure school ventilation system is operating during sampling period.

ᵞIf investigating within space variability, repeat steps 8.2 to 8.6 for the following locations:

- Near the center of the room
- 1m away from center of wall opposite from door

OUTDOOR INVESTIGATION SAMPLING PROTOCOL

Note weather, wind conditions, time of day and any outdoor activities that could affect results. Sampling during or after rain can skew outdoor data.

9.0 Outdoor Control Sampling

9.1 Obtain control sample for RCS Plus® and the Q-Trak® for temperatures above 0°C.
9.2 Take a control sample outdoors, 5 feet from the main entrance of the school, at a height of 3.3 ft (1 m).
9.3 Sample using RCS Plus® and Q-Trak® plus according to section 11.0 and section 13.0 respectively.

10.0 Visual inspection

10.1 Inspect the outdoor air intake surroundings and respond to questions in the HVAC survey.
10.2 After ensuring that supply fan is back on, use smoke tubes to determine if air is flowing into outdoor air intake.
10.3 If water damage or pooling exists at the base of the OAI take a water sample according to section 5a.
10.4 If mould is visible, obtain a tape sample(s) according to the information provided from section 5b.

11.0 RCS Plus®
11.1 Repeat steps 6.1-6.17 from indoor RCS Plus® air sampling
11.2 Using a tripod, place the RCS Plus® vertically. Take sample 1ft away from the outdoor air intake that services the room(s) being sampled.
11.3 Shield outdoor fungal air samples from direct sunlight.

12.0 Velocicalc® Plus
12.1 This instrument cannot be operated at temperatures below 5°C.
12.2 Take measurements when room is unoccupied, as several air vents will likely need to be measured over desks. A ladder may be necessary.
12.3 Use the grid method described in section 7.0 to sample outdoor air intakes (OAI).
12.4 Download data onto a computer at the end of the day.

13.0 Q-Trak®
13.1 This instrument cannot be operated at temperatures below 5 °C
13.2 Take sample near OAIs 1.6 ft (0.5 m) away from the grating.
13.3 Take 15-minute spot measurements so that results may be compared to the ASHRAE 15-minute standard.
13.4 Download data onto a computer at the end of the day.

14.0 End of Day
14.1 Deposit tape and water samples for analysis at the Provincial Public Health Laboratory
14.2 Obtain signature of receipt on Chain of Custody form.
14.3 Decontaminate sample containers with isopropyl alcohol in the staging area of EENV building.
14.4 Ensure all data has been successfully downloaded to computer.
14.5 Prepare investigation tools for next day.

13.0 Q-Trak®
13.1 This instrument cannot be operated at temperatures below 5 °C
13.2 Take sample near OAIs 1.6 ft (0.5 m) away from the grating.
13.3 Take 15-minute spot measurements so that results may be compared to the ASHRAE 15-minute standard.
13.4 Download data onto a computer at the end of the day.

14.0 End of Day
14.1 Deposit tape and water samples for analysis at the Provincial Public Health Laboratory
14.2 Obtain signature of receipt on Chain of Custody form.
14.3 Decontaminate sample containers with isopropyl alcohol in the staging area of EENV building.
14.4 Ensure all data has been successfully downloaded to computer.
14.5 Prepare investigation tools for next day.

[i] Boss, M.J. and Day, D.W. (2001). *Air Sampling and Industrial Hygiene Engineering*. Lewis Publishers: Boca Raton, FL. 271 pp.

[ii] Boss, M.J. and Day, D.W. (2001). Air Sampling and Industrial Hygiene Engineering. Lewis Publishers: Boca Raton, FL. 271 pp.

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Appendix 10: Pre-Screening Survey

Pre-Screening Survey

Title of Project:	Indoor Air Quality in Edmonton and Strathcona County Public Schools	
Principal Investigators:	Steven Probert Capital Health (780) 413-7933	Warren Kindzierski University of Alberta (780) 492-0247
Co-Investigators:	Lisa Johnston Edmonton Public Schools (780) 429-8132	Dale Lechelt Elk Island Public Schools (780) 417-8125
	Paul Steinhubl Elk Island Catholic Schools (780) 467-8896	

Background Information:

Capital Health and the University are investigating the quality of indoor air within public schools. The Project will measure certain indoor air quality parameters (fungal aerosols and ventilation rates) and determine building designs and conditions that may contribute to indoor air quality. The results of this questionnaire will assist the investigators in selecting a representative sample of your schools.

Instructions:

This questionnaire is to be completed by a qualified person designated by your school board's co-investigator, as listed above. Please answer all of the questions by printing in the spaces provided or placing a checkmark in the correct box. Please contact your co-investigator or Steven Probert for assistance. The completed questionnaire is to be returned to your co-investigator **by May 23, 2001**.

School Name: ____

Street Address: ______________________________ Postal Code: ______________

Circle City/County: Edmonton Sherwood Park Strathcona County

Who completed this questionnaire?

Name: ______________________ Phone No.: ______________

Name: ______________________ Phone No.: ______________

1. What category does the school fall into?

K-6: ☐ K-9: ☐ K-12: ☐ 6-9: ☐ 6-12: ☐ 9-12: ☐

2. What is school utilization rate based on the 2001 Alberta Infrastructure guideline? ______________________(%)

3. What type of foundation(s) are found in school excluding portables/pods? (please check all that apply)

Basement: ☐ Slab-On-Grade: ☐ Crawl Space: ☐

4. What year did the initial construction of school take place? ______________

5. Are portables and/or pods present?

Yes: ☐ No: ☐

6. Does school have a forced air ventilation system?

Yes: ☐ No: ☐

7. Has school ever had a modernization (as defined in the 1997 draft of the School Capital Plan) and/or a heating and ventilation system upgrade?

Yes: ☐ No: ☐

8. In the past 5 years, has the school had a history of water damage (e.g. roof leak, plumbing leak, poor surface drainage around buildings)?

Yes: ☐ No: ☐

9. In the past 5 years, has the school had an investigation of IAQ concerns?

Yes: ☐ No: ☐

10. In the past 5 years, has the school ever had to take actions to resolve fungal (eg. mould, mildew) contamination concerns?

Yes: ☐ No: ☐

Appendix 11: Results from *Pre-Screening Survey*

Legend for Table:

1	School Board
2	Level of Schooling
3	Utilization Rate
4	Type of Foundation
5	Year of Initial Construction
6	Portables/Pods?
7	Modernization?
8	Water Damage?
9	IAQ Concerns?
10	Action Against Mould?
EIPS	Elk Island Public Schools
EICS	Elk Island Catholic Schools
EPS	Edmonton Public Schools
K	Kindergarten
S	Slab-On-Grade
C	Crawlspalce
B	Basement
Y	Yes
N	No

School	1	2	3	4	5	6	7	8	9	10
Ardrossan Elementary	EIPS	K-6	75.0	S	1956	N	N	Y	Y	N
Ardrossan Jr/Sr High	EIPS	7 to 12	86.0	S/C	1958	Y	Y	Y	N	N
Bev Facey Community	EIPS	9 to 12	88.5	S	1980	N	N	Y	N	N
Brentwood	EIPS	K-6	83.7	S	1964	N	N	Y	N	N
Campbelltown	EIPS	K-6	88.6	S	1956	Y	N	Y	N	N
Clover Bar	EIPS	7 to 9	108.3	S	1971	N	N	N	N	N
Colchester	EIPS	K-6	63.1	S	1957	N	N	N	N	N
F.R. Haythorne	EIPS	7 to 9	102.4	S	1992	N	N	Y	N	Y
Fultonvale	EIPS	K-9	76.2	S	1975	Y	N	N	N	N
Glen Allen	EIPS	K-6	121.7	S	1972	Y	N	N	N	N
Mills Haven	EIPS	K-6	121.3	S	1971	Y	N	N	N	N
Ministik	EIPS	K-6	100.7	B/S/C	1951	Y	N	Y	N	N
Pine Street	EIPS	K-6	119.5	S/C	1962	N	N	Y	N	N
Salisbury	EIPS	9 to 12	59.3	S/C	1968	N	N	Y	N	N
Sherwood Heights	EIPS	7 to 9	84.7	S	1958	N	N	Y	N	N
Uncas	EIPS	K-6	63.5	S	1977	Y	N	Y	Y	Y
Wes Hosford	EIPS	K-6	103.0	S	1974	Y	N	Y	N	N
Westboro	EIPS	K-6	73.5	S	1970	Y	N	N	N	N
Woodbride Farms	EIPS	K-6	81.4	S	1978	Y	N	Y	N	N
Wye	EIPS	K-6	83.7	S	1954	Y	N	Y	Y	N
Arch Bishop Jordan	EICS	9 to 12	74.0	S	1969	N	Y	N	N	N
Father Kenneth Kearns	EICS	K-9	104.6	S/C	1967	Y	N	N	Y	N
Holy Redeermer	EICS	K-9	97.2	S	1984	Y	N	N	N	N
Jean Vanier	EICS	K-9	119.2	S/C	1973	Y	N	Y	N	N
Madonna	EICS	K-9	130.6	S/C	1974	Y	N	N	Y	N
Our Lady of Perpetual Help	EICS	K-9	111.9	S	1968	Y	Y	N	N	N
St. Luke	EICS	K-9	75.2	S	1983	Y	N	N	Y	N
St. Theresa	EICS	K-9	103.2	S/C	1974	Y	N	N	N	N
Abbott	EPS	K-6	70.8	S	1958	N	N	N	N	N
Academy at King Edward	EPS	K-6	107.2	B	1928	N	N	N	N	N
Afton	EPS	K-6	61.9	S	1967	N	N	N	N	N
Aldergrove	EPS	K-6	99.9	C	1977	Y	N	Y	Y	Y
Allendale	EPS	K-6	57.4	C	1949	N	N	N	Y	N
Athlone	EPS	K-6	58.3	S	1957	N	Y	N	Y	Y
Avalon	EPS	7 to 9	84.0	C	1966	N	Y	N	Y	N
Avonmore	EPS	K-6	66.5	C	1956	N	N	N	Y	N
Balwin	EPS	7 to 9	51.0	C	1961	N	N	N	Y	Y
Bannerman	EPS	K-6	60.9	S	1980	Y	N	N	Y	N
Bataryn	EPS	K-6	73.6	S	1980	Y	N	N	Y	N
Beacon Heights	EPS	K-6	57.8	C	1952	N	Y	N	Y	N
Belgravia	EPS	K-6	63.8	C	1954	N	Y	N	N	N
Bellevue	EPS	K-6	40.6	C	1950	N	N	N	N	N
Belmead	EPS	K-6	57.4	S	1979	Y	N	N	Y	Y

School	1	2	3	4	5	6	7	8	9	10
Belmont	EPS	K-6	65.9	S	1979	Y	N	N	Y	Y
Belvedere	EPS	K-6	46.8	C	1959	N	N	N	N	N
Bisset	EPS	K-6	88.8	S	1990	Y	N	N	N	N
Brander Gardens	EPS	K-6	67.5	S	1976	Y	N	N	Y	Y
Brightview	EPS	K-6	76.8	S	1967	N	N	N	N	N
Britannia	EPS	7 to 9	62.3	S	1957	N	N	N	N	N
Brookside	EPS	K-6	39.7	S	1969	N	N	N	Y	N
Caernarvon	EPS	K-6	79.4	S	1976	Y	N	N	Y	Y
Calder	EPS	K-6	48.7	B	1928	N	Y	N	Y	N
Callingwood	EPS	K-6	73.5	S	1977	Y	N	N	Y	Y
CapilaN	EPS	K-6	42.7	C	1958	N	N	N	N	N
Centennial	EPS	K-6	77.8	S	1982	Y	N	N	Y	Y
Clara Tyner	EPS	K-6	80.6	S	1966	Y	N	N	N	N
Coronation	EPS	K-6	64.1	C	1953	N	N	N	N	N
Crawford Plains	EPS	K-6	101.8	S	1983	Y	N	N	N	N
Crestwood	EPS	K-9	122.8	C	1954	Y	Y	N	Y	Y
D. S. MacKenzie	EPS	7 to 9	81.4	S	1968	Y	N	N	Y	N
Daly Grove	EPS	K-6	90.5	S	1989	Y	N	Y	Y	N
Dan Knott	EPS	7 to 9	73.2	S	1980	Y	N	N	N	N
Delton	EPS	K-6	52.6	S	1946	N	N	N	N	N
Delwood	EPS	K-6	76.1	C	1966	N	N	N	Y	N
Dickinsfield	EPS	7 to 9	56.2	S	1974	N	N	N	N	N
Donnan	EPS	K-9	58.3	C	1948	N	N	Y	N	N
Dovercourt	EPS	K-6	89.4	C	1955	N	Y	N	Y	Y
Duggan	EPS	K-6	58.4	S	1971	Y	N	N	Y	Y
Dunluce	EPS	K-6	80.9	S	1979	Y	N	N	N	N
Earl Buxton	EPS	K-6	96.5	S	1991	Y	N	N	Y	N
Eastglen	EPS	10 to 12	102.0	C	1952	N	N	N	Y	N
Eastwood	EPS	K-9	29.1	B	1922	N	N	Y	Y	N
Edith Rogers	EPS	7 to 9	103.6	S	1975	Y	N	N	N	N
Ekota	EPS	K-6	72.2	S	1977	Y	N	N	Y	N
Ellerslie Campus	EPS	K-9	64.0	S	1959	Y	N	N	N	N
Elmwood	EPS	K-6	34.7	C	1960	N	Y	N	Y	Y
Evansdale	EPS	K-6	72.1	S	1971	Y	N	Y	N	N
Forest Heights	EPS	K-6	58.6	C	1948	N	N	N	N	N
Fraser	EPS	K-6	70.9	S	1984	Y	N	N	N	N
Fulton Place	EPS	K-6	125.7	C	1957	N	N	N	N	N
Garneau/Queen Alexandra	EPS	K-6	25.6	B	1923	N	N	N	N	N
George H. Luck	EPS	K-6	92.8	S	1993	Y	N	N	Y	N
Glendale	EPS	K-6	55.0	S	1952	Y	Y	N	N	N
Glengarry	EPS	K-6	80.5	S	1962	N	N	N	Y	Y
Glenora	EPS	K-6	58.0	B	1940	N	N	N	Y	N
Gold Bar	EPS	K-6	42.7	C	1959	N	N	N	Y	Y
Grace Martin	EPS	K-6	86.7	S	1972	Y	N	N	N	N

School	1	2	3	4	5	6	7	8	9	10
Grandview Heights	EPS	K-9	118.8	C	1960	Y	N	N	N	N
Greenfield	EPS	K-6	95.2	S	1968	N	N	N	N	N
Greenview	EPS	K-6	73.9	S	1980	Y	N	N	Y	Y
Griesbach	EPS	K-9	46.7	C	1954	N	N	N	N	N
Grovenor	EPS	K-6	57.7	C	1949	N	N	Y	N	N
Hardisty	EPS	7 to 9	44.1	C	1956	N	N	N	N	N
Harry Ainlay	EPS	10 to 12	89.5	S	1966	N	N	N	N	N
Hazeldean	EPS	K-6	49.1	C	1950	N	N	N	Y	N
High Park	EPS	K-6	69.7	S	1954	N	Y	N	N	N
Highlands	EPS	7 to 9	64.5	B	1914	N	N	N	N	N
Hillcrest	EPS	7 to 9	73.2	S	1962	Y	N	N	N	N
Hillview	EPS	K-6	54.7	S	1980	Y	N	N	Y	Y
Holyrood	EPS	K-6	83.7	C	1954	Y	Y	N	Y	Y
Homesteader	EPS	K-6	54.7	S	1977	Y	N	Y	Y	Y
Horse Hill	EPS	K-9	23.9	S	1953	N	N	Y	Y	Y
Inglewood	EPS	K-6	56.5	C	1949	N	N	N	N	N
J. A. Fife	EPS	K-6	57.2	S	1969	N	N	N	N	N
J. Percy Page	EPS	10 to 12	107.2	S	1984	N	N	N	Y	N
James Gibbons	EPS	K-6	67.5	S	1947	N	Y	N	N	N
Jasper Place	EPS	10 to 12	79.3	B	1961	N	N	Y	N	N
John A. McDougall	EPS	K-9	32.7	B	1930	N	N	Y	N	N
John Barnett	EPS	K-6	98.8	S	1972	N	N	N	N	N
John D. Bracco	EPS	7 to 9	87.3	S	1992	Y	N	Y	N	N
Julia Kiniski	EPS	K-6	92.1	S	1986	Y	N	N	N	N
Kameyosek	EPS	K-6	69.4	S	1977	Y	N	N	N	N
Kate Chegwin	EPS	7 to 9	85.4	S	1992	Y	N	N	Y	N
Keheewin	EPS	K-6	106.4	S	1981	Y	N	N	Y	Y
Kenilworth	EPS	7 to 9	85.2	C	1962	N	N	N	Y	N
Kensington	EPS	K-6	68.7	C	1958	N	N	N	Y	Y
Kildare	EPS	K-6	94.7	S	1968	Y	N	N	N	N
Killarney	EPS	7 to 9	47.7	C	1958	N	Y	N	N	N
King Edward	EPS	K-6	41.9	S	1958	N	N	N	Y	N
Kirkness	EPS	K-6	74.0	S	1983	Y	N	N	N	N
L. Y. Cairns	EPS	7 to 9	47.9	S	1969	N	N	N	Y	N
L'Académie Vimy Ridge	EPS	6 to 12	27.5	C	1958	N	N	N	N	N
Lago Lindo	EPS	K-6	76.0	S	1990	Y	N	N	N	N
Lansdowne	EPS	K-6	64.3	S	1969	N	N	N	Y	N
LaPerle	EPS	K-6	91.6	S	1983	Y	N	Y	N	N
Lauderdale	EPS	K-6	82.3	C	1954	Y	N	N	Y	N
Laurier Heights	EPS	K-9	78.4	C	1957	N	N	Y	N	N
Lawton	EPS	7 to 9	59.9	C	1956	N	N	Y	Y	N
Lee Ridge	EPS	K-6	91.2	S	1976	Y	N	N	N	N
Lendrum	EPS	K-6	59.3	C	1962	N	N	N	Y	Y
Londonderry	EPS	7 to 9	99.3	S	1969	Y	N	N	N	N

School	1	2	3	4	5	6	7	8	9	10
Lymburn	EPS	K-6	92.8	S	1984	Y	N	N	N	N
Lorelei	EPS	K-6	93.7	S	1977	Y	N	Y	Y	Y
Lynnwood	EPS	K-6	70.6	S	1959	N	Y	N	N	N
M. E. LaZerte	EPS	10 to 12	55.2	S	1970	N	Y	N	N	N
Malcolm Tweddle	EPS	K-6	72.2	S	1976	Y	N	Y	Y	N
Malmo	EPS	K-6	51.3	S	1964	N	N	Y	Y	N
Mary Butterworth	EPS	7 to 9	92.9	S	1992	Y	N	N	N	N
Mayfield	EPS	K-6	67.6	S	1958	N	Y	N	Y	N
McArthur	EPS	K-6	77.4	C	1958	N	N	N	Y	N
McCauley	EPS	K-9	36.7	B	1911	N	N	N	Y	Y
McKee	EPS	K-6	57.5	S	1966	N	N	N	Y	N
McKernan	EPS	K-9	60.7	C	1951	N	Y	N	Y	N
McLeod	EPS	K-6	89.9	S	1972	Y	N	N	Y	N
McNally	EPS	10 to 12	86.4	S	1964	N	Y	N	Y	Y
Meadowlark	EPS	K-6	108.5	S	1957	N	Y	N	N	N
Mee-Yah-Noh	EPS	K-6	71.2	C	1960	N	N	N	N	N
Menisa	EPS	K-6	74.1	C	1981	Y	N	N	Y	Y
Meyokumin	EPS	K-6	67.0	S	1980	Y	N	N	Y	N
Meyonohk	EPS	K-6	98.4	S	1980	Y	N	N	N	N
Michael A. Kostek	EPS	K-6	95.8	S	1994	Y	N	N	N	N
Minchau	EPS	K-6	72.1	C	1984	Y	N	N	Y	N
Montrose	EPS	K-6	46.0	C	1950	N	N	N	Y	Y
Mount Pleasant	EPS	K-6	117.3	C	1953	Y	Y	N	Y	Y
Mount Royal	EPS	K-6	55.8	C	1950	N	N	N	N	N
Newton	EPS	K-6	54.0	C	1955	N	N	N	Y	N
Nrth Edmonton	EPS	K-6	33.7	B	1911	N	N	N	N	N
Nrthmount	EPS	K-6	52.1	S	1970	N	N	N	N	N
Norwood	EPS	K-6	37.6	B	1908	N	Y	N	N	N
Old Scona Academic	EPS	10 to 12	99.2	B	1907	N	Y	N	N	N
Oliver	EPS	K-6	62.1	B	1910	N	Y	N	Y	N
Ormsby	EPS	K-6	50.4	S	1980	Y	N	N	N	N
Ottewell	EPS	7 to 9	91.6	C	1959	N	N	N	N	N
Overlanders	EPS	K-6	78.3	S	1980	Y	N	N	Y	N
Parkallen	EPS	K-6	40.1	C	1951	N	N	N	Y	N
Parkdale	EPS	K-9	51.3	B	1912	N	N	N	Y	N
Parkview	EPS	K-9	79.6	C	1955	N	Y	Y	Y	N
Patricia Heights	EPS	K-6	68.0	S	1968	N	N	N	Y	N
Pollard Meadows	EPS	K-6	58.3	S	1980	Y	N	N	N	N
Prince Charles	EPS	K-6	90.3	C	1948	N	N	N	N	N
Princeton	EPS	K-6	58.5	S	1964	N	N	N	N	N
Queen Elizabeth	EPS	10 to 12	60.8	C	1958	N	N	N	N	N
Queen Mary Park	EPS	K-6	71.4	C	1953	Y	N	N	Y	N
R. J. Scott	EPS	K-9	169.2	S	1958	Y	N	N	N	N
Richard Secord	EPS	K-6	76.7	S	1968	N	N	Y	N	N

School	1	2	3	4	5	6	7	8	9	10
Rio Terrace	EPS	K-6	47.6	S	1961	N	N	N	N	N
Ritchie	EPS	7 to 9	43.9	S	1954	N	N	N	N	N
Rideau Park	EPS	K-6	100.9	S	1977	Y	N	N	N	N
Riverbend	EPS	7 to 9	91.3	S	1974	Y	N	N	N	N
Riverdale	EPS	K-6	101.1	B	1923	N	Y	N	N	N
Ross Sheppard	EPS	10 to 12	96.9	C	1956	N	N	N	N	N
Rosslyn	EPS	7 to 9	76.4	C	1959	N	Y	N	Y	N
Rundle	EPS	K-6	40.4	C	1966	N	N	N	N	N
Rutherford / Idylwylde	EPS	K-6	31.9	B	1911	N	N	N	Y	N
S. Bruce Smith	EPS	7 to 9	108.3	S	1991	Y	N	N	Y	Y
Sakaw	EPS	K-6	64.1	S	1980	Y	N	N	Y	N
Satoo	EPS	K-6	68.0	S	1977	Y	N	N	N	N
Scott Robertson	EPS	K-6	60.3	C	1960	N	N	N	Y	N
Sherbrooke	EPS	K-9	53.6	C	1954	N	N	N	N	N
Sherwood	EPS	K-6	45.6	C	1976	N	N	N	N	N
Sifton	EPS	K-6	52.4	S	1977	Y	N	N	N	N
Spruce Avenue	EPS	K-6	44.6	B	1942	N	N	N	N	N
Steele Heights	EPS	7 to 9	60.2	S	1968	N	N	N	N	N
Steinhauer	EPS	K-6	67.4	S	1977	Y	N	N	N	N
Strathcona	EPS	10 to 12	116.7	C	1953	N	N	N	N	N
T. D. Baker	EPS	7 to 9	89.6	S	1991	Y	N	Y	Y	Y
Talmud Torah	EPS	K-9	60.0	S	1998	N	N	N	Y	Y
Terrace Heights	EPS	K-6	57.3	C	1959	N	Y	N	Y	N
Thorncliffe	EPS	K-6	67.7	S	1972	Y	Y	N	N	N
Tipaskan	EPS	K-6	52.3	S	1982	Y	N	N	Y	N
Velma E. Baker	EPS	K-6	75.8	S	1993	Y	N	Y	N	N
Vernon Barford	EPS	7 to 9	93.7	S	1967	Y	N	N	N	N
Virginia Park	EPS	K-6	96.5	C	1947	Y	Y	N	N	N
W. P. Wagner	EPS	10 to 12	88.9	S	1968	N	Y	Y	N	N
Waverley	EPS	K-6	34.9	S	1966	N	N	Y	N	N
Weinlos	EPS	K-6	77.0	S	1983	Y	N	N	N	N
Wellington	EPS	7 to 9	34.0	C	1956	N	N	N	N	N
Westbrook	EPS	K-6	97.7	C	1966	Y	N	N	N	N
Westglen	EPS	K-6	52.4	B	1940	N	N	N	Y	N
Westlawn	EPS	7 to 9	47.5	S	1968	N	N	N	N	N
Westminster	EPS	7 to 9	47.6	C	1950	N	Y	N	Y	N
Westmount	EPS	7 to 9	40.8	B	1913	N	N	N	N	N
Windsor Park	EPS	K-6	113.7	C	1953	N	Y	N	N	N
Winterburn Westview	EPS	K-12	83.3	C	1957	Y	Y	Y	Y	N
Woodcroft	EPS	K-6	67.7	C	1955	N	N	N	Y	N
York	EPS	K-6	73.6	S	1966	Y	N	N	N	N
Youngstown	EPS	K-6	55.9	S	1959	N	Y	N	N	N

Appendix 12: Introductory Letter

Capital Health

Environmental Health Services

UNIVERSITY OF ALBERTA
Civil and Environmental Engineering

Dear Principal,

The World Health Organization and international environmental health agencies recognize indoor air pollution as a serious threat to human health. In addition, it is recognized that children are a more susceptible sub-population to air pollutants, and that indoor air quality (IAQ) within schools affects both student health and performance.

As a result, Capital Health and the University of Alberta are conducting an exciting new indoor air quality study within Edmonton and Strathcona County. The purpose of this study is to determine the status of IAQ in schools, to develop IAQ investigative techniques and IAQ management strategies. Although, this study has already received the support of your Superintendent, we would also like your consent for this school to participate in the study.

This study will involve a physical inspection of selected rooms and ventilation systems, and monitor important IAQ parameters. In order to obtain representative results, it is essential that sampling occur under normal school operating conditions. This study will require one visit to most schools, and two visits in fall and winter to some schools with each visit lasting 4 to 6 hours. The attached *Information Sheet* and *Conduct Protocol* contain additional information including procedures to be followed by field investigators within the school.

The field investigators will report the results of this study in several different forms. There will be an immediate verbal report of any imminently dangerous conditions and a preliminary written report of the results after each school visit. Lastly, there will also be a final comprehensive report scheduled for completion in summer 2002. These reports will be provided to the school co-investigator, identified on the *Information Sheet*, for distribution to the appropriate school staff. Otherwise, the results of this study will be kept confidential by the field investigators.

As a participating school, the investigators require your assistance in informing people about the study and in scheduling the aforementioned school visits. If you wish to participate, please complete and return the attached *Response/Consent Form* **by**

September 14, 2001. In order to inform staff, parents and students, the investigators would like you to distribute the *Information Sheet* as an attachment to your school newsletter.

If you have any questions or concerns, please contact your school co-investigator. Thank you for your co-operation.

Yours truly,

____

Dr. Warren Kindzierski, PhD., PEng.
Principal Investigator
University of Alberta

____

Dr. Gerald Predy, MD., FRCPC
Medical Officer of Health
Capital Health

Attachments: *Response/Consent Form*
Information Sheet
Conduct Protocol

Appendix 13: Information Sheet

Capital Health

UNIVERSITY OF ALBERTA

Environmental Health Services

Civil and Environmental Engineering

INFORMATION SHEET

Indoor Air Quality in Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools

What is the purpose of the project?

The World Health Organization and international environmental health agencies recognize indoor air pollution as a serious threat to human health. In addition, it is recognized that children are a more susceptible sub-population to air pollutants, and that indoor air quality (IAQ) within schools affects both student health and performance.

As a result, Capital Health and the University of Alberta are conducting an exciting new indoor air quality study within Edmonton and Strathcona County. The purpose of this project is to determine the status of IAQ in schools, to develop IAQ investigative techniques and IAQ management strategies.

What data will be collected?

This study includes IAQ monitoring and a physical inspection of the school. The IAQ parameters monitored include carbon dioxide, carbon monoxide, temperature, humidity, mould, and ventilation rates.

The physical inspection of selected rooms will include source identification of indoor air pollutants, and a determination of the status of ventilation systems serving those rooms.

How will this information be used?

This information will be used to develop more effective IAQ investigative and management strategies. It will allow further development and validation of methods for IAQ monitoring and surveying. It will allow school boards and government to develop 'state of the art' IAQ management strategies.

When will the study be conducted?

This study has several stages including study design, data collection, data analysis and reporting. The study began in January 2001 and requires about 18 months to complete. The schools that consent to participate in the study will receive confirmation in September 2001. The data collection is scheduled from September 2001 to March 2002. Lastly, data analysis and reporting will be done.

The sampling must occur during normal school hours for results to be representative of student exposure. There will be one visit to most schools but there are a few schools needed for two seasonal visits. Based upon school differences, each school visit will require 4 to 6 hours.

How will this study affect the school?

The study is designed to minimize classroom disruption. It is conducted during normal school hours requiring air sampling and inspection in occupied rooms. However, Capital Health designed it after a pilot study (1999/2000) that was successful in minimizing classroom disruption.

In addition to Principal consent, the study requires the patience and support of school staff, and assistance in scheduling the visits and distributing *Information Sheets.*.

The study does not require any assistance or personal information from parents or students.

What are the benefits of this study?

- Improved IAQ investigative methods and management strategies
- School IAQ baseline levels
- Increased public awareness of IAQ
- Healthier staff and students
- Improved learning environments

Who is conducting the study?

Capital Health is conducting the study in cooperation with Edmonton Public Schools, Elk Island Public Schools, and Elk Island Catholic Schools.

The three field investigators identified below are graduate students from the University of Alberta.

How will the information be reported?

The results of this study will be available to the public in a comprehensive report scheduled for release in summer 2002.

The identity of individual schools will be released to the respective school boards and Capital Health, but otherwise the identity will be kept confidential by the investigators.

Where can I get more information?

Steven Probert
Principal Investigator
Project Manager
Capital Health
(780) 413-7933

Warren Kindzierski
Principal Investigator
Project Consultant
University of Alberta
(780) 492-0247

Lisa Johnston
Edmonton Public Schools
Co-Investigator
(780) 429-8132

Dale Lechelt
Elk Island Public Schools
Co-Investigator
(780) 417-8125

Arjen DeVries
Elk Island Catholic Schools
Co-Investigator
(780) 991-1340

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Field Investigator
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(780) 492-8548
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Mary Unobe
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University of Alberta
(780) 492-8548
munobe@ualberta.ca

Appendix 14: Response/Consent Form

Capital Health

UNIVERSITY OF ALBERTA

Environmental Health Services

Civil and Environmental Engineering

Response / Consent Form

Title of Project:	*Indoor Air Quality in Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools.*	
Principal Investigators:	Steven Probert Capital Health (780) 413-7933	Warren Kindzierski University of Alberta (780) 492-0247
Co-Investigators:	Lisa Johnston Edmonton Public Schools (780) 429-8132	Dale Lechelt Elk Island Public Schools (780) 417-8125
	Arjen DeVries Elk Island Catholic Schools (780) 991-1340	
Field Investigators:	Lorelei Betke, Corinne Stocco and Mary Unobe University of Alberta (780) 492-8548 or cstocco@ualberta.ca	

Instructions:

The requested information will provide the principal's consent to participate in the study and enable the investigators to schedule their visit in either fall 2001 or winter 2002. If you need additional information to assist you in making this decision, please call your school board's co-investigator or Capital Health's principal investigator identified above. **Please complete and return this form via facsimile by October 3, 2001 to:**

School IAQ Study
Warren Kindzierski
University of Alberta
FAX # (780) 492-8289

After receiving the completed form, the investigators will contact you to schedule their visit. Thank-you for your co-operation.

School:____

Street Address:__________________________
Postal Code: ________________
Phone No.: _____________ ______
Fax No.: ____________________

1. If you agree to participate, please read the below paragraph and indicate your consent by signing below.

I understand that by signing below, my school will be participating in the indoor air quality investigation that is being completed by Capital Health and the University of Alberta. I know that my school is in no way obligated to participate, and that I have the right to withdraw at any time during the study, without consequence. I have received and read a copy of the information sheet, and have had the opportunity to ask an investigator my questions. I also understand that all data that will be obtained during this study will be kept confidential and will be kept for at least five years in a secure area. I also know that it is possible that the data obtained from the investigation may be looked at again in the future to help answer other study questions.

I agree to allow this school to participate in the study:

____________________ ____________________
Principal's Name Date

____
Principal's Signature

2. In order to facilitate scheduling, please attach a school calendar indicating any holidays, PD Days and other days in which 'normal' room activities may not be occurring in the sample locations (e.g., fieldtrips, school assemblies). If this calendar is not yet available, please fax the response form without it, and the investigators will be as flexible as possible during scheduling.

3. In order to facilitate HVAC investigations, please provide the following information:

Head Custodian's Name ________________________________
Head Custodian's Phone Number __________________________

4. Please list any questions, comments or concerns:

____

Appendix 15: Conduct Protocol

Capital Health

UNIVERSITY OF ALBERTA

Environmental Health Services

Civil and Environmental Engineering

CONDUCT PROTOCOL

Title of Project: *Indoor Air Quality in Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools.*

PRIOR TO SCHOOL VISIT

By mid-September, mail the following to selected schools:

Principal Information Letter
Information Sheet
Response/Consent form
Conduct Protocol

In early October, complete the following tasks:

- Phone call to set up sampling appointment with school (Note: For EPSB schools, no calls to principals before 10:30 am)
- Establish school contact person (Principal or designate)
- Establish facilities contact person with each project co-investigator (Dale, Lisa, Arjen)
- Outline time requirements
- Outline sampling procedure
- Finalize school visits schedule

DAY BEFORE SCHOOL VISIT

- Phone call to school's contact person to confirm visit (For EPSB schools, no calls before 10:30 am if contact person is principal).
- Phone call to facilities services' contact person to confirm meeting time and place for HVAC survey

DAY OF SCHOOL VISIT

Upon Arrival

- Ensure visible placement of identification tags
- Sign in at main office
- Introduce self to school personnel and/or designate
- Meet up with facilities contact person
- Explanation of visit to facilities contact person

Heating Ventilation and Air Conditioning (HVAC) Survey

- Inspect HVAC system and complete survey with assistance of facilities contact person

Room Survey

- In keeping with the *EPSB Blueprints Program,* begin Room Surveys anytime after 10:30am.
- Introduce self to teacher/staff member in each room to be sampled and outline sampling procedure. If requested, briefly explain purpose of study
- Set up equipment while minimizing room disruption
- Sampling to be conducted as per *Sampling Protocol*
- Remove equipment and quietly exit room

Outdoor Sampling

- Access appropriate outdoor air intakes
- Sampling to be conducted as per sampling protocol

Leaving School

- Sign out at main office, and thank contact person for time/assistance
- Advise school administrator, Capital Health and school board's co-investigator of any imminent nature (protocol to be developed).

AFTER VISIT

- Provide school co-investigators with preliminary sampling results as they become available for each school.
- Distribute thank-you notes to schools that participated

Appendix 16: School Maintenance History Survey

Capital Health

Environmental Health Services

UNIVERSITY OF ALBERTA
Civil and Environmental Engineering

SCHOOL MAINTENANCE HISTORY SURVEY

Title of Project:	*Indoor Air Quality in Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools.*	
Principal Investigators:	Steven Probert Capital Health (780) 413-7933	Warren Kindzierski University of Alberta (780) 492-0247
Co-Investigators:	Lisa Johnston Edmonton Public Schools (780) 429-8132	Dale Lechelt Elk Island Public Schools (780) 417-8125
	Arjen DeVries Elk Island Catholic Schools (780) 467-8896	
Field Investigators:	Lorelei Betke, Corinne Stocco and Mary Unobe University of Alberta (780) 492-8548 lbetke@ualberta.ca	

Instructions:

The purpose of this questionnaire is to determine episodes of water damage and recent renovations/upgrades in the school. Maintenance of school mechanical systems will also be assessed and incidence of air quality complaints evaluated. This will assist investigators in the interpretation of sampling results gathered from the various locations in the school.

This school maintenance history survey is to be completed for selected schools by a facilities personnel offsite. It may be most convenient to complete this survey in conjunction with the School Screening Survey since both are completed offsite and are looking for related information.

There are four main questions in this survey, as well as a schematic of the school floor plan that has been included for reference purposes. Please answer all questions by printing in the appropriate boxes. If a question is unclear, please contact a field investigator for assistance. Return to investigators by September 15. Thank-you for your cooperation.

SCHOOL NAME

____

Who completed this questionnaire? Name: ______________________

Phone No.: ______________________

A. School Maintenance History:

1. Complete the table with any incidents of major water damage that occurred within the past five years:

Incident	Phase Number(s)	Room Number(s)	Year of Incident	Was incident resolved? (Yes/No/N/A)	Year Resolved
Roof Leak					
Surface Drainage Leak					
Other (please describe) __________ __________ __________ __________					

2. Indicate if the following renovations/upgrades occurred within the past five years:

Renovation/Upgrade	**Year of work**	**Phase Number(s)**	**Room Number(s)**
Adjustment to Room Size			
Open Room Enclosed			
Room Conversion			

3. Please answer the following set of questions:

a) How often is the HVAC system balanced?

On a routine basis: ☐ As needed: ☐

b) Is there a preventative maintenance program for the HVAC system?

Yes: ☐ No: ☐

If so, is there a method to assess the effectiveness of the HVAC maintenance program?

Yes: ☐ No: ☐

c) Are the air ducts professionally cleaned on a routine basis?

Yes: ☐ No: ☐ Unknown: ☐

d) When were the air ducts last professionally cleaned?

2001 ☐ 2000 ☐ 1999 ☐ Unknown ☐ Other ☐

If other, indicate year of cleaning ________________

4. Please answer the following questions:

a) In the past five years, have the school staff, parents or students reported any concerns about the school's indoor air quality?

Yes ☐ No ☐

b) In the past year, approximately how many of these individuals have reported indoor air quality concerns?

1-10 ☐ 11-30 ☐ 31-50 ☐ >50 ☐

Glossary of terms for the **School Maintenance History Survey**

Term	Definition
Air balancing	The process of measuring the distribution of air supply and the amounts of exhausted air.
Ducts	Conduits through which supply air travels.
Heating, ventilation and air conditioning	Air handling systems designed primarily for temperature, humidity, odour control, and air quality.
Major Water Damage	Damage that occurs repeatedly
Preventative maintenance	Pro-active steps to prevent problems for the HVAC system (eg. cleaning schedule).

Appendix 17: Screening Survey

Capital
Health

UNIVERSITY OF ALBERTA

Environmental Health Services **Civil and Environmental Engineering**

SCHOOL SCREENING SURVEY

Title of Project:	*Indoor Air Quality in Edmonton Public Schools, Elk Island Public Schools and Elk Island Catholic Schools.*	
Principal Investigators:	Steven Probert Capital Health (780) 413-7933	Warren Kindzierski University of Alberta (780) 492-0247
Co-Investigators:	Lisa Johnston Edmonton Public Schools (780) 429-8132	Dale Lechelt Elk Island Public Schools (780) 417-8125
	Arjen DeVries Elk Island Catholic Schools (780) 991-1340	
Field Investigators:	Lorelei Betke, Corinne Stocco and Mary Unobe University of Alberta (780) 492-8548 or (cstocco@ualberta.ca)	

Instructions:

This survey will enable investigators to select rooms in your school for sampling of indoor air quality parameters. If a question is unclear, please refer to the glossary of terms or contact one of the field investigators for assistance. Thank-you for your co-operation.

This survey is to be completed by a qualified person appointed by the school board co-investigators listed above. The completed survey is to be **submitted to your co-investigator by September 15, 2001.**

Please begin by obtaining a schematic of the school floor plan that identifies all rooms by number and function. This schematic should be stapled to the back of this survey. Outline each 'construction phase' in red and identify it as Phase I, II, III, IV, etc. Each portable or pod should be identified as a separate 'construction phase'. Rooms with a history of water damage and/or visible or suspected fungal growth should be indicated with an asterisk (*), as shown in the sample schematic.

Please complete the attached Screening Survey for each 'construction phase', answering all questions by placing a check mark or appropriate number in the correct box(es). If there is more than one correct box, check all that apply.

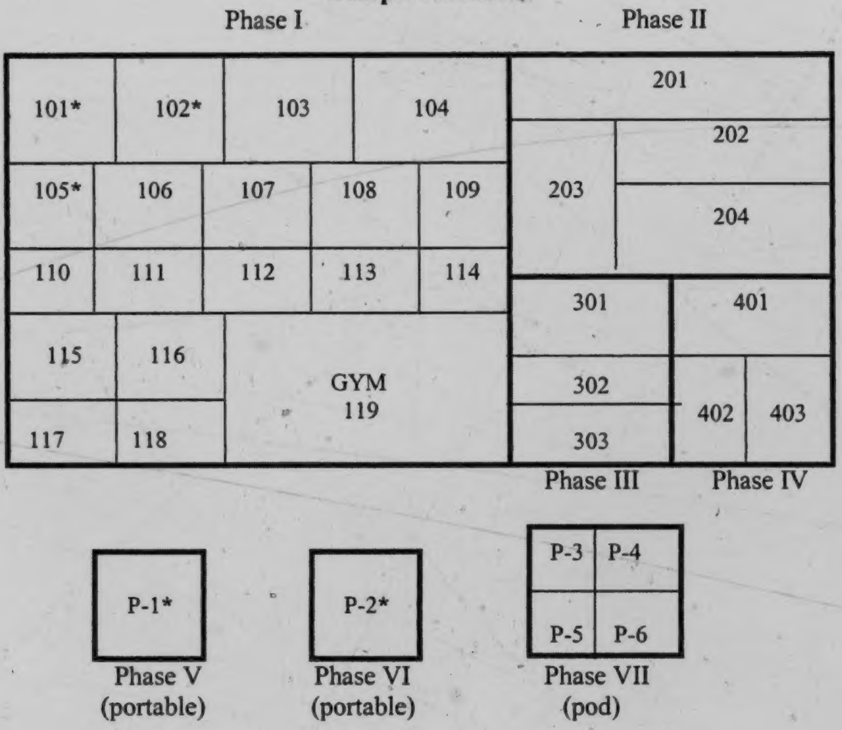
Who completed this questionnaire?

Name: ______________________________ Phone No.: __________________

Name: ______________________________ Phone No.: __________________

Date of completion (dd/mm/yy): _____________________

Sample schematic


Phase I
Phase II
101*
102*
103
104
201
202
105*
106
107
108
109
203
204
110
111
112
113
114
301
401
115
116
GYM
119
302
402
403
117
118
303
Phase III
Phase IV
P-3
P-4
P-1*
P-2*
P-5
P-6
Phase V
(portable)
Phase VI
(portable)
Phase VII
(pod)

* Denotes rooms that have had fungal investigation and/or water damage.

Glossary of terms for the Screening Survey

Term	Definition
Construction Phase	A stage in the development of the project that occurs after the construction contract has been awarded and until the certificate of substantial completion has been issued.*
HVAC System	These are systems that service multiple rooms and exclude unit serving a single room (eg. unit ventilator, small forced-aired furnace in a pod or portable). Please use the school's identifier, or room numbers that they service.
Masonry	Stone-work, other than brick.
Permanent	The main school building structure, that cannot easily be relocated.
Pod	This is typically one unit that has several classrooms within it. It may or may not be connected to the permanent building structure via hallways.
Portable	This is typically a one classroom unit which has its own HVAC system. This structure may or may not be attached to the permanent building structure via hallways, and can be relocated to other locations.
Suspected mould growth	Musty smells.
Visible mould growth	>0.5 square foot of mould For example: ceiling tiles, ductwork, wallboard panels.
Water damage	Damage that occurs repeatedly. For example: roof leak, water main break, and surface drainage leak.

* Based on the 2001 Alberta Infrastructure Guidelines

Appendix 18: Scheduling Template

School	Date of Visit	School Hours	Contact person	Set up Q-Trak® before 8am?	Blueprint Classes	Actual Class #

Appendix 19: Equipment List

- Biotest Hycon RCS Plus®, Model 940310, s/n 6699
    - 2 NiCad batteries
    - 1 carrying case
    - 1 AEG battery charger
    - 1 remote control
    - 1 tripod
    - 1 manual
- TSI Q-Trak®, Model 8551, s/n 50682
    - 1 carrying case
    - 1 power adaptor
    - 1 download cable
    - 1 probe stand
    - 1 manual
- TSI Q-Trak®, Model 8551, s/n 50684
    - 1 carrying case
    - 1 power adaptor
    - 1 download cable
    - 1 probe stand
    - 1 manual
- TSI Velocicalc®
    - 1 carrying case
    - 1 power adaptor
    - 1 download cable
    - 1 manual
- Bulk/Surface Sampling equipment:
    - clear plastic vials
    - transparent adhesive tape
    - wax paper
    - Ziploc™ baggies
- Transportation equipment:
    - insulated cooler
    - ice packs
- Data log books, pens
- Laboratory 4°C cooler
- Measuring Tape

Appendix 20: Room Survey

Capital
Health
Environmental Health Services

UNIVERSITY OF ALBERTA
Civil and Environmental Engineering

ROOM SURVEY

Name of School: ____________________

Room Number: ____________________

Survey Information		Comments
General information		
1	Construction phase	
2	Room volume (ft^3)	V = L * W * H =
3	Number of occupants in the room (other than investigators):	0 ☐ 1-10 ☐ 11-20 ☐ 1-30 ☐ >31 ☐
4	Function of the room?	Classroom ☐ Food Studies ☐ Lab ☐ Other ☐ ________
5	Level of room activity	Low ☐ High ☐ None ☐
6	Is there a noticeable odour?	Yes ☐ No ☐
7	List number of plants in the room	
8a	Is there a carpet in the room?	Yes ☐ No ☐
8b	If yes, describe its condition	Good ☐ Worn ☐ Dirty ☐ Other ☐ ________
8c	Estimate area of coverage	< 100 ft^2 ☐ 100 – 200 ft^2 ☐ > 200 ft^2 ☐
Heating and Ventilation		
9	Sources of room ventilation	Central HVAC: Yes ☐ No ☐ Windows: Open ☐ Closed ☐ N/A ☐ Doors: Open ☐ Closed ☐ Unit Ventilator: On ☐ Off ☐ Auto ☐ N/A ☐ Local Exhaust: On ☐ Off ☐ Auto ☐ N/A ☐
10a	Is there an outdoor air intake?	Yes ☐ No ☐
10b	Condition of OAI?	Clean ☐ Partially matted ☐ Clogged ☐ N/A ☐
Potential Sources of Contamination		
11a	Is there a portable humidifier?	Yes ☐ No ☐

11b	Condition of portable humidifier	Clean ☐ Mineral Buildup ☐ Mould Growth ☐ Other ☐ ______
12	Air freshener present?	Yes ☐ No ☐
13a	Any pets in the classroom?	Yes ☐ No ☐
13b	If yes describe	
14	Is the classroom dusty?	Yes ☐ No ☐ Somewhat ☐
15	Are there sources of CO_2 other than human breath?	Yes ☐ No ☐ Describe______ ______

16. Using the legend, complete the following table for evidence of water damage:

LEGEND→ ***A: < 1 square foot ,*** ***B: 1 – 10 square feet*** ***C: > 10 square feet***

Area	**Water Evidence (✓)**				**Area Type and Size (A, B, C)**				**Sample taken (✓)**
	Dry Stain	Wet Stain	Conden-sation	Ponding	Ceiling	Floor	Wall	Window	
1									
2									
3									
4									
5									

Indicate ventilation sources (Provide schematic) CW = closed window OW = open window CD = closed door OD = open door FH = fume hood H = heater	

Appendix 21: Perception Survey

Perception Survey

School ___________________ Room Number _______ Date _____________

INSTRUCTIONS: Please rate how strongly you agree or disagree with each of the following statements by placing a check mark in the appropriate box.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Statement
					Today, the classroom smells musty[a].
					Today, the classroom is stuffy[b].
					Today, the classroom is cold.
					Today, the classroom is hot.
					Today, the air in the classroom is dry.
					Today, the air in the classroom is humid[c].

[a] **Musty** Stale or mouldy in odour.

[b] **Stuffy** Lacking sufficient ventilation.

[c] **Humid** Moist or damp.

Appendix 22: HVAC Survey

HVAC SURVEY

1. Answer the following questions regarding the air handling system identified below:

Air handling system ID	
Type of ventilation system	Hot water boiler ☐ Steam boiler : ☐ Furnace : ☐ Forced air : ☐ Unit ventilator: ☐ Roof top : ☐
Phase(s) and /or room (s) serviced	
Function	Heating: ☐ Humidifying: ☐ Cooling: ☐ Dehumidifying: ☐ Other: ☐ ____________

2. Description and condition of heating, cooling and reheating coils, humidifiers and drain pans:

Description	Heating Coils	Cooling Coils	Drain Pan	Reheat Coil	Humidifier
Clean					
Slime or mould buildup*					
Clogged			--		
Other ____________					
Not accessible					
Doors well-sealed?	Yes ☐ No ☐	Yes ☐ No ☐	--	--	--

*take tape sample

3. Questions pertaining to indoor / outdoor air mixing:

Appearance of main mixing box	Clean ☐ Dry ☐ Dirty ☐ Wet ☐ No access ☐
Control of mixing box	Pneumatic ☐ DDC ☐ Other ☐ ____________
Indoor : Outdoor mixing ratio	:
Outdoor delivery at all times?	Yes ☐ No ☐

4. Filter type and condition:

Dual stage filter?	Yes ☐ No ☐
Filter type	Box filter ☐ Bag filter ☐ Roll filter ☐ HEPA ☐ Other ☐
Condition of filter	Clean ☐ Build up ☐ Clogged ☐
Tight fitting filter?	Yes ☐ No ☐
Magnehelix reading	< 1 ☐ 1 – 1.5 ☐ >1.5 ☐

5. Description of outdoor air intake (OAI) & surrounding areas.

Obstructed?	Yes ☐ No ☐
Bird screen?	Yes ☐ No ☐

Insect screen?	Yes ☐ No ☐
Sources of CO?	Yes ☐ No ☐
Protection from rain/snow?	Yes ☐ No ☐
Evidence of standing water?	Yes ☐ No ☐
Sources of contamination?	Yes ☐ No ☐
Distance between exhaust and intake	0-10 ft ☐ >10 ft ☐

6. General condition of the system:

.Water collecting anywhere except the drain pan?	Yes ☐ No ☐
Complete air handling shutdown?	Evenings ☐ Weekends ☐ N/A ☐
Partial air handling shutdown	Evenings ☐ Weekends ☐ N/A ☐
Self regulated	Yes ☐ No ☐
Mechanical room cleanliness	Chemical storage Yes ☐ No ☐ Clean Yes ☐ No ☐
Supply fan operating?*	Yes ☐ No ☐ Unknown ☐
Exhaust fan operating?*	Yes ☐ No ☐ Unknown ☐

Comments:

Appendix 23a: Standard Operating Procedure – Biotest RCS Plus® Air Sampler

1. Sterile gloves should always be worn when handling air sampler and agar strips.
2. Before using Biotest RCS Plus for first time, charge batteries.
3. To decontaminate Biotest RCS Plus, spray or wipe housing with a solution of 70% ethanol or a disinfectant harmless to polycarbonate. The rotor must not come into contact with alkaline solutions.
4. To insert agar strip, remove protection cap by rotating it in a counter clockwise direction, and remove rotor from magnetic flange.
5. Pull back the protective wrapper of the agar strip by 4 cm and remove strip.
6. Slide the strip into the rotor with the culture medium facing inwards; the top of the agar strip marked with the batch number and type should be flush with the guide plate of the rotor.
7. Replace the rotor onto the magnetic flange and replace protection cap.
8. To turn on instrument, press the **[RESET]** key. The last sampling volume or a residual, unprocessed volume will appear in the display.
9. The instrument may store a total of 10 sample volumes. The first seven memory locations are permanently set to the preset values 10, 20, 50, 100, 200, 500 and 1000 litres in ascending order. Three memory locations are also available for entering individual volume settings between 1 and 1999 litres.
10. To adjust sample volume, use the **[+]** and **[-]** keys. A value one greater than the value shown in the display is selected using the **[+]** key and one less than the value shown in the display using the **[-]** key.
11. Individual selectable volumes may be entered in three additional programmable positions beyond the 1000 liter sample volume. To enter an individual value, press the **[RESET]** key along with the **[+]** or **[-]** key. Briefly pressing the **[+]** or **[-]** key will enable fine adjustment. If the key is pressed for longer than about 1 second, the volume will change at the rate of approximately 100 liters per second until the key is released.
12. To start the Air Sampler, press the **[ON/OFF]** key.

13. After the set volume of air has been sampled, the measuring process will end automatically. The value >>000<< will appear in the display and an alarm will sound. This may be turned off by pressing **[RESET].**

14. To interrupt the current measurement process, press the **[ON/OFF]** key.

15. To remove the agar strip, remove the protection cap, then the rotor and then using the tab, pull the agar strip from the rotor.

16. Place the agar strip into the protective wrapper with the culture medium facing downwards.

17. Seal the protective wrapper using a slide seal or adhesive tape.

18. Label the agar strip with identification.

Notes:

- Instrument can be operated in a vertical or horizontal position; may also be attached. to tripod by threaded attachment in the base of the housing.
- Air flows at a constant rate that is approximately 50 L/min.
- Remove the rotor from instrument for transportation purposes.

23b: Standard Operating Procedure – Q-Trak® IAQ Monitor Model 8851

1. Press the **[ON/OFF]** key to power the Q-TRAK.

2. Slide the probe into the stand, and keep away from human contact while taking measurements.

3. When the self-check is complete, the Q-TRAK will be in '*Survey Mode*', and the **[CO$_2$]**, **[CO]**, **[Temp]**, and **[Humidity]** keys can be pressed to display individual readings.

4. Press the **[SAMPLING MODE]** key to select between Survey, LOG 1, LOG 2, and LOG 3 modes.

    a. *Survey* mode – Allows for simultaneous measurements of all four parameters. Each new sample taken in this mode erases the previous sample data.

    b. *Log* mode – Allows for recording of the data points for later retrieval and analysis. LOG 1 is preset to measure all four parameters. LOG 2 & 3 modes can be programmed using TRAKPRO software. Data recorded using these modes will not be erased unless the memory is cleared.

        i. Press the **[LOGGING INTERVAL]** key while the Q-TRAK is in the LOG mode to view the logging interval which sets the averaging period for recording data in LOG 1 mode (1, 5, 15, or 30 minutes). Press and hold the **[LOGGING INTERVAL]** key to change the value. The TRAKPRO software is required to change the logging interval of LOG 2 and 3.

5. The Q-TRAK display is updated every second, however it is possible to display a moving average over the past 2, 5, 10, 15, or 20 seconds. Press the **[TIME CONSTANT]** key to view the current time-constant. To change the value, press and hold the key. When the desired value is displayed, immediately release the key.

6. Once the mode is selected, press the **[SAMPLE]** key to start (or stop) data sampling.

7. Regardless of mode, pressing the **[STATISTICS]** key repeatedly allows the sequential viewing of the average, minimum and maximum readings, and can be done while the sampling is in-progress.

8. Press the **[ON/OFF]** key to shut off the Q-TRAK. The memory of the Q-TRAK is not erased when the power is off.

23c. Standard Operating Procedure - Velocicalc® Air Flowrate Instrument

1. Press the **ON** key to turn on the Velocicalc Plus and press arrows to scroll down until velocity/flowrate reading is obtained. Then press **[ENTER].**
2. Select test ID and press **[ENTER].**
3. Slide switch "I" into upward position to turn on the backlighter if this is desired.
4. Press sample interval key to display current time constant. Scroll and select time interval in order to slow down fluctuation in the readings. Press **[ENTER]**.
5. Select log and input the logging interval desired then press **[ENTER]**.
6. Select log and input the logging interval desired then press **[ENTER]**.
7. Press **[SETTING STORAGE OPTION]** to ON in order to log data.
8. Take measurements by putting probe at least 3 inches into air stream. Press **[SAMPLE]** to start sample.
9. Press **[SAMPLE]** to stop sample to record data over time.
10. Press **[CLEAR]** to advance to next ID. Repeat steps 8 and 9.
11. To view statistics, press and hold **[STATISTICS]** arrow and select desired test ID. Press **[ENTER].**

Appendix 24: Moulds Cultured from Aerosol Samples

Acremonium
Alternaria
Aspergillus flavus
Aspergillus fumigatus
Aspergillus glaucus "group"
Aspergillus niger
Aspergillus versicolor
Beauvaria
Chaetomium
Cladosporium
Doratomyces
Epicoccum
Fusarium
Mucor
Non-Sporulating
Paecilomyces
Penicillium
Phoma
Rhizopus
Scopulariopsis
Trichothecium
Ulocladium
Vertillicium
Yeast

Appendix 25: Mould Data (CFU/m^3)

Legend for Table:

ID	Room Number
R	Room
OAI	Outdoor Air Intake
C	Control
D	Duplicate
W	Within Space
-	Non-detectable

School	ID	Total	*Cladosporium*	*Penicillium*	*Alternaria*	Non-Spor.
1a	3R	170	120	17	-	-
1a	4R	46	23	-	-	-
1a	5R	64	17	17	-	7
1a	6R	24	17	-	-	-
1a	7C	363	197	-	50	-
1a	2OAI	1400	710	310	90	-
2a	8R	93	33	-	33	27
2a	10R	150	13	7	123	7
2a	11R	60	20	-	27	-
2a	12C	59	20	3	-	13
2a	9OAI	119	33	3	-	37
3a	13R	100	17	17	17	-
3a	14R	30	10	-	3	7
3a	16aR	73	20	3	17	13
3a	16bR	67	-	30	20	-
3a	15C	3	-	-	-	3
3a	17OAI	261	67	87	90	-
3a	18C	189	33	13	20	13
4a	19R	37	7	3	10	17
4a	20R	30	13	-	7	10
4a	21R	46	13	-	10	23
4a	22R	40	30	-	7	3
4a	23OAI	81	20	17	3	-
4a	24C	113	27	13	13	-
12	25R	27	-	-	7	10
12	26R	17	-	3	7	7
12	27R	13	-	3	-	10
12	28R	33	3	-	-	10
12	29C	53	-	3	-	7
5	30R	107	33	-	30	20
5	31R	91	17	-	7	13
5	32R	26	13	-	-	3
5	33R	67	13	10	13	7
5	34R	800	-	87	-	-
5	35OAI	223	53	17	63	-
6a	36R	114	17	-	13	17
6a	37R	93	40	10	-	17
6a	38R	70	27	-	23	20
6a	40R	26	13	-	-	10
6a	41R	51	27	-	7	17
6a	43R	107	37	10	23	20
6a	39C	-	-	-	-	-
6a	42C	123	30	67	-	-
7a	44R	30	7	3	-	-

School	ID	Total	*Cladosporium*	*Penicillium*	*Alternaria*	Non-Spor.
7a	45R	44	10	-	7	7
7a	46R	3	3	-	-	-
7a	47R	33	3	-	10	7
7a	48R	13	10	-	-	3
7a	49C	40	7	10	3	7
21a	50R	236	13	223	-	-
21a	51R	54	17	27	-	10
21a	52R	16	13	-	-	3
21a	53R	-	-	-	-	-
21a	54R	3	-	-	-	3
8	55R	42	-	13	23	3
8	56R	16	-	-	-	13
8	57R	29	-	3	13	13
8	58R	6	3	-	-	3
8	59R	-	-	-	-	-
8	60R	10	7	-	-	-
8	61R	36	-	-	16	16
8	62R	6	-	-	-	3
8	63R	17	10	-	-	7
8	64C	30	-	-	-	7
20a	65R	6	-	-	-	3
20a	66R	10	3	-	-	7
20a	67R	29	-	-	10	10
20a	68R	23	3	-	-	7
14a	69R	26	13	-	-	3
14a	70R	60	10	7	3	13
14a	71C	-	-	-	-	-
14a	72R	56	3	3	17	23
14a	73R	27	13	-	-	7
14a	74R	27	-	-	-	7
18	75R	70	53	3	-	-
18	76R	33	20	-	-	13
18	77R	63	30	-	20	10
18	78R	50	20	-	10	13
18	79R	16	3	-	-	-
18	80R	33	10	-	17	6
18	81R	23	13	3	-	-
18	82R	23	23	-	-	-
18	83R	43	27	3	-	13
18	84R	23	17	6	-	-
18	85OAI	760	617	13	57	73
13	86R	26	7	-	3	-
13	87R	7	-	7	-	-
13	88R	6	3	-	-	3
13	89R	7	7	-	-	-

School	ID	Total	*Cladosporium*	*Penicillium*	*Alternaria*	Non-Spor.
13	90R	87	10	-	-	30
13	91R	20	3	-	-	-
13	92R	13	3	-	-	7
13	93R	3	-	-	-	3
13	94R	3	-	-	-	3
13	95aR	7	-	-	-	7
13	95bC	194	60	47	-	-
15	96R	70	-	7	-	-
15	97R	47	10	7	20	3
15	98R	20	13	3	-	-
15	99R	40	17	-	7	3
15	100R	20	3	7	-	-
15	101R	17	-	7	-	-
15	102R	22	3	3	-	-
15	103R	53	23	-	13	-
15	104R	51	7	-	7	-
15	105R	43	-	20	-	-
15	106C	167	-	17	-	-
17	107R	29	20	-	3	3
17	108R	20	10	-	-	10
17	109R	23	17	-	6	-
17	110R	10	7	-	-	3
17	111OAI	201	167	-	-	10
17	112C	513	367	53	10	30
16	113C	-	-	-	-	-
16	114R	40	10	-	7	13
16	115R	6	3	-	-	3
16	116aR	16	3	-	-	-
16	116bR	23	-	7	13	-
16	117R	16	-	3	-	10
16	118R	6	-	-	-	3
16	119R	43	17	3	-	13
16	120R	29	3	-	13	10
16	121R	6	3	-	-	3
16	122C	173	20	10	-	20
19	123R	34	7	-	13	7
19	124R	20	-	-	-	-
19	125R	-	-	-	-	-
19	126R	16	-	-	13	3
19	127R	10	-	-	-	7
19	128R	40	16	7	-	16
19	129R	6	3	-	-	3
19	130R	-	-	-	-	-
19	131R	-	-	-	-	-
19	132R	17	-	-	7	-

School	ID	Total	*Cladosporium*	*Penicillium*	*Alternaria*	Non-Spor.
19	133OAI	246	107	13	10	40
11a	134R	10	-	-	-	7
11a	135R	17	-	-	-	-
11a	136R	20	-	-	13	7
11a	137R	26	-	-	13	13
9	138R	210	183	-	-	20
9	139R	67	57	-	3	3
9	140R	57	37	-	3	17
9	141R	-	-	-	-	-
9	142R	33	17	-	13	-
9	143R	30	-	-	-	13
9	144R	7	7	-	-	-
9	145R	64	47	-	-	17
9	146R	83	63	-	-	17
9	147R	117	67	-	20	30
9	148OAI	261	77	10	-	10
9	149C	187	67	-	13	-
22	150R	33	-	10	3	-
22	151R	63	23	20	10	3
22	152R	217	-	40	-	-
22	153R	139	33	40	-	-
22	154R	90	-	20	-	17
22	155R	141	-	37	-	17
22	156R	196	43	60	10	13
22	157aC	186	33	13	10	23
22	157bR	78	47	7	7	-
22	158R	33	-	17	13	-
22	159R	110	40	-	10	17
10	160R	317	27	273	-	-
10	161R	650	-	580	-	-
10	162R	96	13	70	13	-
10	163R	196	13	183	-	-
10	164R	227	-	200	-	-
10	165R	180	-	120	-	33
10	166R	194	10	87	-	67
10	167R	217	50	67	20	50
23	1C	-	-	-	-	-
23	2R	-	-	-	-	-
23	3D	-	-	-	-	-
23	4C	-	-	-	-	-
23	5D	24	-	-	-	10
23	6R	-	-	-	-	-
23	7C	530	-	120	-	30
24	8R	-	-	-	-	-
24	9R	-	-	-	-	-

School	ID	Total	*Cladosporium*	*Penicillium*	*Alternaria*	Non-Spor.
24	10R	-	-	-	-	-
24	11R	-	-	-	-	-
24	12R	3	3	-	-	-
24	13R	-	-	-	-	-
24	14R	7	-	-	7	-
24	15C	130	-	10	-	10
25	16C	80	-	-	-	10
25	17R	10	3	-	-	-
25	18R	-	-	-	-	-
25	19R	-	-	-	-	-
25	20R	13	3	-	-	3
7b	21R	-	-	-	-	-
7b	22D	67	-	-	-	-
7b	23R	7	-	-	-	7
7b	24R	3	3	-	-	-
7b	25R	3	-	-	-	-
7b	26R	3	-	3	-	-
7b	27C	110	-	-	-	-
26	28R	7	-	-	-	-
26	29R	3	-	-	-	-
26	30R	33	-	3	-	-
26	31R	-	-	-	-	-
26	32R	3	-	3	-	-
26	33R	-	-	-	-	-
26	34C	30	-	10	-	-
4b	35R	47	-	-	-	-
4b	36R	6	-	-	-	3
4b	37C	-	-	-	-	-
4b	38R	3	-	-	-	3
4b	39R	-	-	-	-	-
4b	40R	-	-	-	-	-
4b	41R	-	-	-	-	-
4b	42C	200	10	-	-	-
27	43R	37	-	-	-	-
27	44R	26	-	-	-	-
27	45R	97	-	27	-	20
27	46R	7	-	-	-	-
27	47R	10	-	-	-	-
27	48R	-	-	-	-	-
27	49C	160	-	-	-	-
28	50R	10	-	-	-	7
28	51D	13	-	-	-	3
28	52R	17	-	-	-	7
28	53R	6	-	-	-	3
28	54R	6	-	-	-	-

School	ID	Total	*Cladosporium*	*Penicillium*	*Alternaria*	Non-Spor.
28	55R	14	-	-	7	7
28	56C	100	20	10	-	-
29	57R	-	-	-	-	-
29	58R	-	-	-	-	-
29	59R	3	-	-	-	-
29	60R	3	-	-	-	-
29	61R	3	-	-	3	-
29	62C	93	-	-	-	-
2b	63R	-	-	-	-	-
2b	64R	-	-	-	-	-
2b	65R	-	-	-	-	-
2b	66R	-	-	-	-	-
2b	67C	50	-	-	-	-
30	68R	-	-	-	-	-
30	69R	7	-	-	-	7
30	70R	-	-	-	-	-
30	71R	10	-	-	10	-
30	72R	150	-	150	-	-
30	73R	-	-	-	-	-
30	74C	67	-	-	-	-
31	75R	3	-	3	-	-
31	76R	0	-	-	-	-
31	77R	0	-	-	-	-
31	78R	10	-	10	-	-
31	79R	160	-	160	-	-
31	80R	7	-	7	-	-
31	81C	46	13	-	-	-
1b	82R	10	-	-	-	-
1b	83R	6	-	-	-	3
1b	84R	0	-	-	-	-
1b	85C	40	-	20	-	10
6b	86R	14	-	7	-	-
6b	87R	0	-	-	-	-
6b	88R	3	-	-	-	3
6b	89R	3	-	-	-	3
6b	90C	104	-	3	-	17
32	90R	3	-	-	-	-
32	91R	0	-	-	-	-
32	92R	0	-	-	-	-
32	93R	0	-	-	-	-
32	94R	83	-	-	-	-
32	95R	0	-	-	-	-
32	96C	0	-	-	-	-
21b	97R	-	-	-	-	-
School	**ID**	**Total**	***Cladosporium***	***Penicillium***	***Alternaria***	**Non-Spor.**

School	ID	Total	*Cladosporium*	*Penicillium*	*Alternaria*	Non-Spor.
21b	98R	-	-	-	-	-
21b	99R	-	-	-	-	-
21b	100R	-	-	-	-	-
21b	101C	30	-	-	-	-
33	102R	-	-	-	-	-
33	103R	-	-	-	-	-
33	104R	-	-	-	-	-
33	105R	-	-	-	-	-
33	106R	-	-	-	-	-
33	107R	-	-	-	-	-
33	108C	20	-	-	-	-
3b	109R	-	-	-	-	-
3b	110R	3	-	3	-	-
3b	111R	3	-	-	-	-
3b	112R	3	-	-	-	3
3b	113C	10	-	-	-	-
34	114R	6	-	-	-	3
34	115R	-	-	-	-	-
34	116R	-	-	-	-	-
34	117R	117	-	50	10	20
34	118C	-	-	-	-	-
34	119R	60	-	-	-	-
34	120C	40	-	-	-	-
20b	121R	-	-	-	-	-
20b	122R	-	-	-	-	-
20b	123R	-	-	-	-	-
20b	124R	3	-	-	-	3
20b	125C	100	-	-	-	20
35	126R	-	-	-	-	-
35	127R	-	-	-	-	-
35	128R	-	-	-	-	-
35	129R	17	-	-	-	-
35	130R	-	-	-	-	-
35	131R	-	-	-	-	-
35	132C	50	-	-	-	10
14b	133R	3	-	3	-	-
14b	134R	13	-	3	-	-
14b	135R	-	-	-	-	-
14b	136R	30	-	-	-	-
36	137R	-	-	-	-	-
36	138R	3	-	-	-	-
36	139R	-	-	-	-	-
36	140R	-	-	-	-	-
36	141R	3	-	-	-	-
36	142C	10	-	-	-	-

11b	143R	3	-	-	-	3
11b	144R	-	-	-	-	-
11b	145R	-	-	-	-	-
11b	146R	-	-	-	-	-
11b	147C	-	-	-	-	-
37	148R	7	-	-	-	-
37	149R	-	-	-	-	-
37	150R	-	-	-	-	-
37	151R	10	-	-	-	7
37	152R	17	-	17	-	-
37	153R	-	-	-	-	-
37	154C	40	-	10	-	-
38	155R	-	-	-	-	-
38	156R	-	-	-	-	-
38	157R	-	-	-	-	-
38	158R	-	-	-	-	-
38	159R	-	-	-	-	-
38	160R	-	-	-	-	-
38	161C	10	-	-	-	-
39	162R	-	-	-	-	-
39	163R	-	-	-	-	-
39	164R	-	-	-	-	-
39	165R	3	3	-	-	-
39	166R	83	-	50	-	-
39	167R	-	-	-	-	-
39	168C	10	-	-	-	-
40	169R	-	-	-	-	-
40	170R	-	-	-	-	-
40	171R	40	-	-	-	3
40	172R	6	-	-	3	-
40	173R	-	-	-	-	-
40	174R	-	-	-	-	-
40	175C	80	3	-	-	-
41	176R	-	-	-	-	-
41	177R	3	-	-	-	-
41	178R	-	-	-	-	-
41	179R	3	-	-	-	-
41	180R	6	-	-	-	-
41	181R	23	-	3	-	-
41	182C	20	-	-	-	-
42	183R	10	-	-	-	-
42	184R	-	-	-	-	-
42	185R	-	-	-	-	-
42	186R	-	-	-	-	-
42	187R	3	-	-	-	-
School	**ID**	**Total**	***Cladosporium***	***Penicillium***	***Alternaria***	**Non-Spor.**

42	188R	-	-	-	-	-
42	189C	-	-	-	-	-
43	190R	-	-	-	-	-
43	191R	-	-	-	-	-
43	192R	-	-	-	-	-
43	193R	-	-	-	-	-
43	193bR	6	-	-	-	-
43	194R	-	-	-	-	-
43	195C	150	-	-	-	-

Appendix 26: Aitchison's Method: Summary of Calculations

Legend for Table:

X_d	Sample Mean
S_d^2	Sample Variance
$\hat{x}$	Adjusted Overall Mean
$\hat{S}$	Adjusted Overall Standard Deviation

Mould	Round	X_d	S_d^2	$\hat{x}$	$\hat{S}$
Cladosporium	Both	19.2	574	6.34	16.4
	1	20	590	13.5	26.0
	2	3.00	0	0.0920	0.527
Penicillium	Both	41.1	7.60×10^3	9.30	44.7
	1	34.4	3.64×10^3	12.5	41.9
	2	29.5	2.47×10^3	3.08	18.7
Alternaria	Both	13.5	240	2.84	8.96
	1	14.2	259	5.82	13.8
	2	7.40	10.5	0.272	1.55
Non-Sporulating	Both	10.4	90.2	3.87	7.66
	1	11.1	84.6	9.37	9.10
	2	7.87	108	1.11	4.92

Appendix 27: Humidity and Temperature Data

Legend for Table:

ID	Room Number
OUT	Outside Control
OAI	Outdoor Air Intake
HE	Home Economics Room
L	Location (For Within Space Subset)
SR	Shelter Room

School	ID	Humidity (%)	Temperature (°C)
1	OUT	26.5	14.3
1	12OAI	42.5	4.9
1	12	25.5	19.4
2	219	28.6	18.3
2	219OAI	36.8	5.4
2	112	32	17.3
2	217	27.1	20.2
2	OUT	34.7	11.9
2	112	27	21
3	3	26.1	21.4
3	6OAI	26.5	9.7
3	8	24.8	21.8
3	OUT	35.1	7.7
3	6	24.9	21.5
4	OUT	10.3	10.7
4	12OAI	42.9	5.8
4	4	28.1	21.5
4	3	30.3	20.5
4	12	29.9	20.2
12	171	30.1	20.2
12	178	26.3	23.7
12	OUT	32.6	7.8
12	179	25.6	21.8
5	6OAI	49.4	11.7
5	4	33.2	21.3
5	OUT	41	9.4
5	8	30.7	21
5	6	31.7	20.7
6	3	35.3	20
6	15	30.5	21.2
6	8	28.7	21
6	10	27.4	19.5
6	OUT	60.7	0.3
6	20	31.6	21.3
7	17	37.2	20.7
7	7	27.7	20.6
7	21	31.2	22.2
7	4OAI	44.3	0.9
7	4	23.3	23.2
21	S204	24.9	24.8
21	M16	27.6	24.6
21	C207	25.3	22.9
21	C212	27.6	22.9
21	OUT	40.2	5.4
8	6	23.1	22.4
8	2	24.3	22
8	3	24.3	21.6

School	ID	Humidity (%)	Temperature (°C)
8	**8**	**27.3**	**19**
8	OUT	38.1	5
20	15	32.7	19.8
20	11	30	20.5
20	11OAI	42.7	3.1
14	1	32.9	19.8
14	11	32.7	20.8
18	11L2	25.5	23.5
18	11L3	25.7	22
18	7L1	27.1	22
18	7L2	26.5	21.5
18	7OAI	27.4	13.6
18	7	24.9	21.6
13	327	29.5	22.8
13	327	29	23
13	327	28.8	23.4
13	OUT	38.1	7.2
13	327OAI	48.6	4.5
13	329	28.7	21.4
15	12	26.3	23.2
15	13	27.1	21.1
15	12	27.9	21
15	12	27.7	21.1
15	4	24.7	23.8
17	229	24.3	21.7
17	221	23.6	22.7
17	221OAI	33	9.4
17	OUT	34.2	9.8
17	115	24.8	22.9
16	OUT	40.5	5.7
16	101L3	25.4	22.3
16	101L2	25.9	22.3
16	101L1	24.6	22.7
16	106L1	25.3	24.6
19	6L1	30.6	21.2
19	6L2	27.8	22
19	6L3	28	22.2
19	15L1	27.6	24.5
19	15L2	25.6	24.5
19	15L3	26.5	24.2
19	HEL1	29.1	23.3
19	HEL2	27.5	23
19	HEOAI	39.3	3.4
19	HEL3	24.8	22.3
11	10	25.4	18.2
11	17	23.9	19
11	17OAI	35.3	3.2
9	HEL1	28	22.2

School	ID	Humidity (%)	Temperature (°C)
9	HEL3	29.3	23.3
9	HEL2	28.7	22.6
9	HEOAI	36.4	8.8
9	OUT	37.6	8.3
9	115L2	27.5	22.7
9	115L1	27	22.6
9	108L3	28.5	23.1
9	108L2	29.7	23.1
9	108L1	33.7	21.8
9	115	25.7	21.5
22	205	30.7	23.6
22	205L2	28.4	24.4
22	205L3	28	24.3
22	202L1	30.6	23.9
22	202L2	31.7	23.4
22	OUT	29.5	13.4
22	101L1	29.5	23
22	101L2	29.4	24.5
22	101L3	30	25
22	201	30.7	22.5
10	205L2	32.8	22.4
10	205L3	32.5	22.7
10	208L1	33.7	22.7
10	208L2	32.6	22.7
10	203L1	33	23.4
10	203L2	32.2	23.4
10	203L3	33.7	23.5
10	OUT	27.7	9.6
23	P	19.7	20.5
23	101	21.2	22.5
23	101	19.7	20.5
24	22	17	22.8
24	19	22.2	18.1
24	20	21.3	22.6
24	23	18.6	21.8
24	21	18.8	23.6
24	7	17.1	22.5
25	7	17.6	20.1
25	12	13.8	22.5
7	4	16.6	22.1
7	21	25.6	19.7
7	7	19.5	21.2
7	17	23.7	23.9
26	6	20.2	20.3
26	3	18.1	21
26	1	18.8	19.2
26	2	15.3	20.4
4	4	15	23.7

School	ID	Humidity (%)	Temperature (°C)
4	7	13.3	24.5
4	2	19.3	18.8
4	3	15	23.4
4	5	20.3	20.5
27	11	25.3	20.4
27	20	19	21.4
27	5	15.9	21.2
27	21	19.8	21.4
27	SR	20.6	24.5
28	2	21.6	18.2
28	17	20.4	22.3
28	6	19.8	20.4
28	3	19.4	21.6
28	231	28.6	22.3
29	4	23.1	19.7
29	12	22.5	22.1
29	13	23.1	22.5
2	4	21.2	21.8
2	217	24.7	19.4
2	219	24.2	20.5
30	13	21.9	20.2
30	53	24.7	21.4
30	55	23.4	21
30	43	24.4	21.8
30	11	25.4	21.5
31	152	23.1	22.2
31	130	22.3	21.4
31	222	27.1	19.8
31	186	24.6	21.2
1	4	21	19.4
1	12	20.1	21.2
6	8	22.8	19.1
6	20	23.6	21.7
6	3	22.5	21.5
6	15	20.2	21.3
32	5	19.8	23.4
32	18	26	18.6
32	8	23.6	20.5
32	6	22.5	20.9
32	51	23.2	21.3
21	S204	14.7	21.3
21	M6	18.6	21.2
21	C212	16.6	21.6
33	115	18.9	19.9
33	119	23	18.6
33	110	19.3	20.8
33	106	18.5	21.8
33	101	19.5	22.3

School	ID	Humidity (%)	Temperature (°C)
3	8	21.8	21.8
34	227	20.7	22.9
34	225	29.6	20.1
3	3	23.2	21.6
34	128	26.3	22.7
34	114	20.3	22.9
20	20	18.6	22.6
20	15	18.4	21.8
20	11	20.4	19.8
35	7	16.7	20.1
35	1	14.8	21.6
35	12	16.1	21.4
35	5	17.4	22.2
14	1	21.5	18.5
36	205	16.3	20.9
36	102	14.7	21.8
36	103	14.7	20.9
36	203	18.6	20.7
11	1	18.6	19.4
11	17	23.6	18.8
11	10	19.3	22.7
37	120	22.6	21.5
37	122	21	23
37	235	21.4	23.8
37	236	21.6	24.6
38	2	20.8	18.8
38	16	21.5	21.8
38	15	22.6	21.7
38	7	19.3	22.9
39	2	20.3	18.7
39	16	20.6	22.7
39	13	20.3	22.7
40	301	20.2	22.3
40	303	19.1	23.2
40	202	19.4	20.4
41	106	16.6	22.7
41	216	15.8	22.1
41	212	16	16
41	322	16.8	23.1
42	4	18.9	20.4
42	7	18.1	21.3
42	5	17.2	22.5
42	13	19.7	22.3
43	114	21	18.6
43	107	17.6	21.4
43	203	19.5	22.5
43	210	16.5	23.6
43	206	19.5	21.8

Appendix 28: Calculations of Best-Fit Model for Flowrate Using Maximum Least Estimate Method

Readings from Same Diffuser (m^3/h)		Predicted Y	$(Y-Y^\wedge)^2$
Velocicalc (x)	Alnor (Y)		
313.96	246.38	333.1015475	7520.627
250.45	246.38	297.90316	2654.636
313.6	263.38	332.902029	4833.313
281.08	271.87	314.8788585	1849.762
325.22	288.86	339.3420426	2548.437
436.72	297.36	401.1373538	10769.74
197.82	305.86	268.7346647	1378.291
415.81	305.86	389.5486546	7003.791
329.86	339.84	341.9136143	4.299876
186.93	356.83	262.6992303	8860.602
871.11	492.77	641.8841269	22235.02
809.41	518.26	607.688874	7997.524
871.11	543.74	641.8841269	9632.27
809.41	552.24	607.688874	3074.578
422.85	577.73	393.4503496	33958.99
526.3	603.22	450.7842055	23236.67
773.11	1002.53	587.5707592	172191.2
		SS	319749.7
		Root Mean Square	33.2626

Parameter Estimates	
B_o (intercept)	159.0993
B (slope)	0.554218
Best-Fit Model	Corrected Flowrate = 0.554218(Flowrate Velocicalc) + 159.0993

Appendix 29: Ventilation Data

Legend for Table:

SCH	School Identification
ID	Room Number
VEL	Velocity of Air at Vent
R	Return Vent
S	Supply Vent
A	Area
FLW	Flow Rate
CFLOW	Corrected Flow Rate (Using Best-Fit Model)
V	Volume
ACH	Air Exchange Rate

SCH	ID	VEL (ft/s)	R/S	Duct A (ft^2)	FLW (ft^3/s)	FLW (m^3/h)	CFLOW	S-R	Room V(m^3)	ACH
3	8	9.2496	S	1.21	11.192016	1141.048415	791.4888706	435.0481443	231.21	1.9
3	8	2.8864	R	1.21	3.492544	356.0718459	356.4407263			
3	6	10.5944	S	1.21	12.819224	1306.945525	883.4320351	598.7518275	210.04	2.9
3	6	1.8368	R	1.21	2.222528	226.5911747	284.6802076			
5	6	7.0192	S	2	14.0384	1431.242957	952.319909	552.2891156	222.74	2.5
5	6	2.132	R	2	4.264	434.723328	400.0307934			
7	17	6.8552	S	2	13.7104	1397.802701	933.7867172	534.6825834	280.02	1.9
7	17	1.2136	R	3.5	4.2476	433.0513152	399.1041338			
7	4	7.9704	S	2	15.9408	1625.196442	1059.812421	719.0878418	356.39	2.0
7	4	0.9184	R	3.5	3.2144	327.7145088	340.7245796			
7	7	9.9712	S	2	19.9424	2033.167565	1285.917361	802.4872049	280.02	2.9
7	7	1.64	R	3.5	5.74	585.20448	483.4301565			
14	1	5.9696	S	0.49	2.925104	298.220203	324.3783045	837.8507649	212.60	3.9
14	1	9.7088	S	0.69	6.699072	682.9837885	537.6212093			
14	1	5.8712	S	0.49	2.876888	293.3044854	321.6539253			
14	1	2.2632	R	1.46	3.304272	336.8771389	345.8026742			
14	6	11.2176	S	0.49	5.496624	560.39181	469.6785282	1121.000869	253.71	4.4
14	6	10.9224	S	0.69	7.536456	768.3567621	584.936448			
14	6	7.6752	S	0.49	3.760848	383.4259753	371.6008772			
14	6	1.7712	R	1.46	2.585952	263.6429783	305.2149841			
14	11	8.8232	S	2	17.6464	1799.085773	1156.185019	1414.156667	205.58	6.9
14	11	1.1152	R	1.46	1.628192	165.9974308	251.0980641			
18	11	6.1664	S	2.75	16.9576	1728.861235	1117.265316	509.0697124	205.58	2.5
18	11	3.4112	R	2.33	7.948096	810.3242834	608.1956037			
18	7	7.9376	S	2.75	21.8284	2225.449037	1392.483214	1410.894825	250.74	5.6
18	7	2.4272	R	2.33	5.655376	576.576894	478.648593			
19	6	7.4784	S	1.84	13.760256	1402.88562	936.6037624	497.0602041	219.46	2.3
19	6	3.1816	R	1.56	4.963296	506.0179538	439.5435583			
19	15	11.48	S	1.84	21.1232	2153.552486	1352.636852	1080.781613	219.46	4.9
19	15	1.2792	R	1.56	1.995552	203.4505175	271.8552389			
25	3	1.8696	S	0.35	0.65436	66.71331072	196.0730176	-548.0783895	225.99	-2.4
25	3	15.3176	S	0.35	5.36116	546.5809843	462.02432			
25	3	5.4448	S	0.35	1.90568	194.2878874	266.7771444			
25	3	1.5744	S	0.35	0.55104	56.17963008	190.2350622			
25	3	1.6728	R	0.24	0.401472	40.93087334	181.7839268			
25	3	1.968	R	0.24	0.47232	48.15396864	185.7870962			
25	3	1.8368	R	0.24	0.440832	44.94370406	184.0079098			
25	3	2.0664	R	0.24	0.495936	50.56166707	187.121486			
25	3	1.7712	R	0.24	0.425088	43.33857178	183.1183166			

SCH	ID	VEL (ft/s)	R/S	Duct A (ft^2)	FLW (ft^3/s)	FLW (m^3/h)	CFLOW	S-R	Room V(m^3)	ACH
25	3	2.3288	R	0.24	0.558912	56.98219622	190.6798588			
25	3	1.9024	R	0.24	0.456576	46.54883635	184.897503			
25	3	1.7384	R	0.24	0.417216	42.53600563	182.67352			
25	3	1.7712	R	0.24	0.425088	43.33857178	183.1183166			
25	7	2.0008	S	0.35	0.70028	71.39494656	198.6676645	-340.2738614	225.99	-1.5
25	7	11.3488	S	0.35	3.97208	404.9615002	383.5362527			
25	7	6.3632	S	0.35	2.22712	227.0593382	284.9396723			
25	7	7.5112	S	0.35	2.62892	268.0236518	307.6428323			
25	7	0.5248	S	0.35	0.18368	18.72654336	169.4778874			
25	7	2.0336	R	0.24	0.488064	49.75910093	186.6766894			
25	7	2.132	R	0.24	0.51168	52.16679936	188.0110792			
25	7	1.968	R	0.24	0.47232	48.15396864	185.7870962			
25	7	2.0336	R	0.24	0.488064	49.75910093	186.6766894			
25	7	2.0992	R	0.24	0.503808	51.36423322	187.5662826			
25	7	2.0664	R	0.24	0.495936	50.56166707	187.121486			
25	7	2.1648	R	0.24	0.519552	52.9693655	188.4558758			
25	7	2.4272	R	0.24	0.582528	59.38989466	192.0142486			
25	7	1.7056	R	0.24	0.409344	41.73343949	182.2287234			
7	17	6.396	S	2	12.792	1304.169984	881.8937802	533.7559238	280.02	1.9
7	17	1.6728	R	2	3.3456	341.0906112	348.1378564			
7	7	10.7912	S	2	21.5824	2200.368845	1378.58332	1050.831975	280.02	3.8
7	7	0.8528	R	3.5	2.9848	304.3063296	327.7513454			
26	5	9.184	S	1.5	13.776	1404.490752	937.4933556	615.3019678	241.85	2.5
26	5	2.8864	R	1	2.8864	294.2742528	322.1913878			
26	3	7.2488	S	1.5	10.8732	1108.544486	773.4746082	486.4962847	289.09	1.7
26	3	2.2632	R	1	2.2632	230.7377664	286.9783234			
26	2	9.7088	S	1.5	14.5632	1484.747366	981.9730159	1506.748493	578.18	2.6
26	2	5.4776	R	1	5.4776	558.4522752	468.6036031			
26	2	14.8256	S	1.5	22.2384	2267.249357	1415.649704			
26	2	4.6576	R	1	4.6576	474.8516352	422.2706236			
3	8	11.0864	S	1.21	13.414544	1367.63959	917.0697782	612.2069247	231.21	2.6
3	8	2.132	R	1.21	2.57972	263.0076134	304.8628535			
3	6	15.0552	S	1.21	18.216792	1857.238378	1188.414239	713.1201541	210.04	3.4
3	6	4.6248	R	1.21	5.596008	570.5242076	475.2940853			
35	7	8.6592	S	2	17.3184	1765.645517	1137.651827	759.8608638	224.95	3.4
35	7	1.9352	R	2	3.8704	394.5950208	377.7909632			
35	1	9.4136	S	2	18.8272	1919.470694	1222.904509	656.0749897	207.64	3.2
35	1	3.608	R	2	7.216	735.685632	566.8295196			
35	5	6.9536	S	2	13.9072	1417.866854	944.9066323	400.3169429	224.39	1.8
35	5	3.4112	R	2	6.8224	695.5573248	544.5896894			

SCH	ID	VEL (ft/s)	R/S	Duct A (ft^2)	FLW (ft^3/s)	FLW (m^3/h)	CFLOW	S-R	Room V(m^3)	ACH
35	10	5.9368	S	2	11.8736	1210.537267	830.0008432	392.9036662	224.95	1.7
35	10	2.46	R	2	4.92	501.60384	437.097177			
14	1	7.544	S	2.85	21.5004	2192.008781	1373.950022	998.3830423	212.60	4.7
14	1	2.624	R	1.46	3.83104	390.5821901	375.5669802			
14	11	7.2816	S	2	14.5632	1484.747366	981.9730159	660.5229557	253.71	2.6
14	11	1.968	R	1.46	2.87328	292.9366426	321.4500602			
14	6	9.6104	S	2.25	21.6234	2204.548877	1380.899969	1018.862219	253.71	4.0
14	6	2.46	R	1.46	3.5916	366.1708032	362.0377502			
37	121	5.6744	S	1.25	7.093	723.145536	559.8795727	35.4910623	250.12	0.14
37	121	4.428	R	1.46	6.46488	659.1074458	524.3885104			
37	122	9.9712	S	1.56	15.555072	1585.870701	1038.017388	600.2159496	250.12	2.4
37	122	3.3784	R	1.46	4.932464	502.8745697	437.8014383			
37	235	2.1648	S	1.96	4.243008	432.5831516	398.8446691	230.4787732	323.53	0.71
37	235	0.0656	R	2.5	0.164	16.720128	168.3658959			
37	236	8.9544	S	2.25	20.1474	2054.067725	1297.500606	976.0505461	304.50	3.2
37	236	1.968	R	1.46	2.87328	292.9366426	321.4500602			
37	239	10.1024	S	1.96	19.800704	2018.721374	1277.911023	729.6146948	304.50	2.4
37	239	2.7552	R	2.5	6.888	702.245376	548.2963278			
									Min	-2.4
									Max	6.9
									Mean	2.6

Appendix 30: Spearman's Rank Correlation Calculations

Legend for Table:

C	*Cladosporium*
A	*Alternaria*
NS	Non-Sporulating
P	*Penicillium*

1	Indoor Airborne Mould : Outdoor Airborne Mould
2	Indoor Airborne Mould : Temperature
3	Indoor Airborne Mould : Humidity
4	Indoor Airborne Mould : Air Exchange Rate
5	Indoor Airborne Mould : Occupancy

r_s	Spearman's Rank Correlation Coefficient where $r_s = 1 - (\frac{6\sum d^2}{n^3 - n})$
n	Number of Samples Ranked
d	Rank Difference

Mould	Correlation	Round	$\sum d^2$	$6(\sum d^2)$	n	n^3-n	r_s
C	1	Both	177114	1062684	255	16581120	0.93591
		Fall	73240	439440	96	884640	0.50325556
		Winter	51274	307644	159	4019520	0.9234625
A		Both	71868	431208	255	16581120	0.97399404
		Fall	44236	265416	96	884640	0.69997
		Winter	377	2262	159	4019520	0.999437
NS		Both	290107	1740642	255	16581120	0.89502265
		Fall	80433	482598	96	884640	0.45446962
		Winter	27091	162546	159	4019520	0.95956084
P		Both	679142	4074852	255	16581120	0.75424748
		Fall	82196	493176	96	884640	0.44251221
		Winter	64081	384486	159	4019520	0.90434529
C	2	Both	1708118	10248708	233	12649104	0.189768066
		Fall	231371	1388226	111	1367520	0.015141278
		Winter	546287	3277722	122	1815726	0.805185364
A		Both	2225320	13351920	233	12649104	0.055562513
		Fall	200291	1201746	111	1367520	0.121222359
		Winter	506378	3038268	122	1815726	0.673307536
NS		Both	1658469	9950814	233	14649104	0.213318667
		Fall	211403	1268418	111	1367520	0.07246841
		Winter	381268	2287608	122	1815726	0.259886128
P		Both	2075310	12451860	233	12649104	0.015593516
		Fall	177886	1067316	111	1367520	0.219524395
		Winter	396254	2377524	122	1815726	0.309406816
C	3	Both	1395758	8374548	233	12649104	0.337933501
		Fall	177774	1066644	111	1367520	0.220015795
		Winter	560215	3361290	122	1815726	-0.851209929
A		Both	2133610	12801660	233	12649104	-0.012061
		Fall	182898	1097388	111	1367520	0.1975342
		Winter	519154	3114924	122	1815726	-0.715525
NS		Both	1319977	7919862	233	12649104	0.373879604
		Fall	157464	944784	111	1367520	0.309126009
		Winter	387394	2324364	122	1815726	-0.280129271
P		Both	2045122	12270732	233	12649104	0.02991295
		Fall	166651	999906	111	1367520	0.26881801
		Winter	404682	2428092	122	1815726	-0.33725683
C	4	Both	17846	107076	54	157410	0.319763674
		Fall	2934	17604	28	21924	0.197044335
		Winter	4833	28998	26	17550	-0.652307692
A		Both	26577	159462	54	157410	-0.013036021
		Fall	3337	20022	28	21924	0.0868754242
		Winter	5394	32364	26	17550	0.99982906
NS		Both	19237	115422	54	157410	0.266742901
		Fall	2399	14394	28	21924	0.343459223
		Winter	3931	23586	26	17550	-0.343931624
P		Both	23589	141534	54	157410	0.100857633
		Fall	2802	16812	28	21924	0.233169

		Winter	3279	19674	26	17550	-0.12103
Mould	**Correlation**	**Round**	**$\sum d^2$**	**$6(\sum d^2)$**	**n**	**n^3-n**	**r_s**
C	5	Both	2684937	16109622	261	17779320	0.093912366
		Fall	307605	1845630	122	1815726	0.016469445
		Winter	826171	4957026	139	2685480	0.845862192
A		Both	3167176	19003056	261	17779320	0.06882918
		Fall	218888	1313328	122	1815726	0.27669263
		Winter	791855	4751130	139	2685480	0.7691921
NS		Both	2400447	14402682	261	17779320	0.189919412
		Fall	207119	1242714	122	1815726	0.315582858
		Winter	581137	3486822	139	2685480	-0.298398052
P		Both	3151994	18911964	261	17779320	-0.0637057
		Fall	255504	1533024	122	1815726	0.155696399
		Winter	635918	3815508	139	2685480	-0.42079181

Appendix 31: Pair Sample T-test for Effect of Gender on Perception

Statistical Measure	*Women*	*Men*
Mean	20	20
Variance	314	256
Observations	35	35
Pearson Correlation	0.59	
Hypothesized Mean Difference	0	
Df	34	
t Stat	-4.2E-16	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.7	
P(T<=t) two-tail	1	
t Critical two-tail	2.0	

Appendix 32: Results from *Perception Survey*

Legend for Table:

7

M	Male
F	Female
SA	Strongly Agree
A	Agree
N	Neutral
D	Disagree
SD	Strongly Disagree

School	Gender	Date	Musty	Stuffy	Cold	Hot	Dry	Humid
23	M	01/21/02	A	A	N	N	SA	D
	F	01/21/02	D	N	D	D	A	D
24	F	01/22/02	SA	SA	N	N	SA	SD
	F	01/22/02	A	A	SD	N	A	D
25	M	01/23/02	D	SA	SD	SD	SA	SD
	F	01/23/02	A	SA	N	N	SA	SD
7	F	01/24/02	N	N	SA	SD	A	SD
	M	01/24/02	SD	A	SA	SD	SA	SD
26	F	01/25/02	A	SA	D	D	SA	SD
	F	01/25/02	A	A	N	N	SA	SD
4	F	01/28/02	D	D	D	D	SA	SD
	F	01/28/02	SD	D	N	SD	A	SD
27	F	01/29/02	A	A	D	N	SA	SD
	F	01/29/02	D	D	D	D	A	D
28	F	01/30/02	N	A	N	N	A	D
	F	01/30/02	SA	SA	N	N	SA	SD
29	F	01/31/02	N	A	N	N	SA	SD
	F	01/31/02	D	D	D	A	A	D
30	F	02-05-02	-	N	A	SD	N	N
	M	02-05-02	N	A	A	D	A	D
31	F	02-06-02	SD	A	N	N	A	SD
	F	02-06-02	D	D	N	SD	A	SD
1	F	02-25-02	D	SD	SD	N	SA	SD
	F	02-25-02	SD	SD	A	SD	SA	SD
6	F	02/26/02	D	D	D	D	D	D
	F	02/26/02	SA	SA	SD	D	SA	SD
32	F	02/27/02	D	N	N	N	SD	SD
	F	02/27/02	D	D	D	D	SA	SD
33	F	03-01-02	SA	SA	D	D	A	SD
	F	03-01-02	D	N	N	D	SA	SD
3	F	03-04-02	A	A	SD	SA	SA	SD
	F	03-04-02	D	D	A	D	A	D
34	F	03-05-02	SD	SA	D	D	SA	SD
	F	03-05-02	D	D	SD	N	A	D
20	F	03-06-02	D	N	D	N	A	D
35	F	03-07-02	SD	D	SA	SD	SA	SD
14	M	03-08-02	SD	SD	N	N	SA	SD
36	M	03-11-02	D	A	SD	N	A	D
	F	03-11-02	N	A	N	N	SA	SD
11	M	03-12-02	SD	SD	SD	D	D	N
	F	03-12-02	A	A	N	N	SA	SD
37	F	03/13/02	SD	SD	N	N	A	SD
	F	03/13/02	N	A	D	N	SA	N
38	F	03/14/02	A	A	D	D	SA	SD

School	Gender	Date	Musty	Stuffy	Cold	Hot	Dry	Humid
39	F	03/15/02	A	SA	SD	SA	SA	SD
40	F	03/18/02	D	A	N	N	A	D
	F	03/18/02	-	SA	D	D	SA	SD
41	F	03/19/02	SD	D	N	N	A	D
	F	03/19/02	D	D	D	N	N	D
42	F	03/20/02	D	A	SD	A	A	SD
	F	03/20/02	N	N	A	D	SA	SD
43	F	21-03-02	D	N	A	SD	A	D

Summary of Data

	Musty	Stuffy	Cold	Hot	Dry	Humid
SD	10	5	10	9	1	33
D	19	12	15	16	2	16
N	7	8	18	23	2	3
A	10	17	6	2	20	0
SA	4	10	3	2	27	0
Total	50	52	52	52	52	52

Appendix 33:Comparison Between Perception Data and Environmental Measurements

Legend for Table:

ID	Room Number

Legend for Perceived Environment:

1	Strongly Agree
2	Agree
3	Neutral
4	Disagree
5	Strongly Disagree

School	ID	Measured Environment			Perceived Environment					
		Humidity	Temp (°C)	Mould (CFU/m^3)	Dry	Humid	Stuffy	Musty	Hot	Cold
23	101	21.2	20.5	0	2	4	3	4	4	4
24	22	17	22.8	0	1	5	1	1	3	3
24	18	22.2	18.1	0	2	4	2	2	3	5
25	7	17.6	20.1	0	1	5	1	4	5	5
7	21	25.6	19.7	67	1	5	2	5	5	1
26	6	20.2	20.3	33	1	5	1	2	4	4
26	3	18.1	21	0	1	5	2	2	3	3
4	4	15	23.7	3	1	5	4	4	4	4
4	3	15	23.4	0	2	5	4	5	5	3
27	11	25.3	20.4	97	1	5	2	2	3	4
27	20	19	21.4	10	2	4	4	4	4	4
28	2	21.6	18.2	10	2	4	2	3	3	3
28	17	20.4	22.3	6	1	5	1	1	3	3
29	4	23.1	19.7	0	1	5	2	3	3	3
29	12	22.5	22.1	3	2	4	4	4	2	4
30	53	24.7	21.4	10	2	4	2	3	4	2
31	152	23.1	22.2	7	2	5	2	5	3	3
31	130	22.3	21.4	10	2	5	4	4	5	3
1	4	21	19.4	6	1	5	5	4	3	5
1	12	20.1	21.2	0	1	5	5	5	5	2
6	8	22.8	22.8	14	1	5	1	1	4	5
6	15	20.2	21.3	3	4	4	4	4	4	4
32	8	23.6	20.5	0	1	5	4	4	4	4
32	6	22.5	20.9	0	5	5	3	4	3	3
33	119	23	18.6	0	1	5	3	4	4	3
3	3	23.2	23.2	0	1	5	2	2	1	5
34	225	29.6	20.1	6	2	4	4	4	3	5
36	205	16.3	20.9	0	2	4	2	4	3	5
36	103	14.7	20.9	3	1	5	2	3	3	3
11	17	23.6	18.8	0	3	3	5	5	4	5
37	120	22.6	21.5	7	2	5	5	5	3	3
37	122	21	23	0	1	3	2	3	3	4
38	16	21.5	21.8	0	1	5	2	2	4	4
39	13	20.3	22.7	83	1	5	1	2	1	5
40	303	19.1	23.2	40	2	4	2	4	3	3
40	202	19.4	20.4	0	1	5	1	-	4	4
41	322	16.8	23.1	23	2	4	4	5	3	3
42	13	19.7	23.2	0	2	5	2	4	2	5
43	203	19.5	22.5	0	2	4	3	4	5	2